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AUTOMOBILE ENGINEER

DESIGN · PRODUCTION · MATERIALS

Vol. 40 No. 529 JULY, 1950 PRICE: 2s. 6d.

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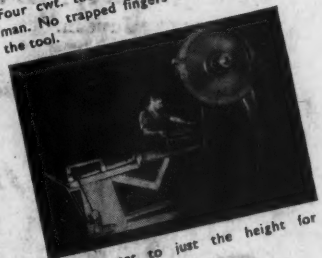

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Publishers: ILIFFE & SONS LTD., DORSET HOUSE, STAMFORD STREET, LONDON, S.E.1
Telegrams: Sliderule, Sedist, London Telephone: Waterloo 3333 (60 lines)

COVENTRY:	BIRMINGHAM, 2:	MANCHESTER, 3:	GLASGOW, C.2:
8-10, CORPORATION ST.	KING EDWARD HOUSE, NEW ST.	260, DEANSGATE	26B, RENFIELD ST.
Telegrams: Autocar, Coventry	*Telegrams:* Autopress, Birmingham	*Telegrams:* Iliffe, Manchester	*Telegrams:* Iliffe, Glasgow
Telephone: Coventry 5210	*Telephone:* Midland 7191-7	*Telephone:* Blackfriars 4412	*Telephone:* Central 4857

PUBLISHED MONTHLY—SECOND THURSDAY

Annual Subscription: Home and Overseas £1 17s. 6d., including the Special Number; U.S.A. and Canada $6.00

VOL. XL. NO. 529 JULY, 1950 PRICE 2S. 6D.

Le Mans

TO the technical man the Grand Prix d'Endurance has become rather too mixed an affair to be of real interest or significance on a comparative basis. The machines taking part this year were, in fact, of so diverse a character as to rule out any profitable comparisons. How, for example, is it possible to make a useful evaluation of the respective merits of a racing machine of high cost, and the ordinary commercial production car, costing only a fraction of such prices? There are, however, some grounds for satisfaction regarding the performance of British cars. Notwithstanding that the highest placed all-British car was fifth, it shared first place on the index of performance. British-built cars were also third and fourth on the same basis.

A creditable performance

Unfortunately the Grand Prix d'Endurance overshadows the index of performance, but taking all the factors into account, the gaining of fifth place with a 2½-litre closed car against thinly disguised racing machines and other vehicles with disproportionately large engines is highly creditable.

Space forbids any lengthy consideration of the rules. There does, however, seem to be a measure of unfairness in allowing near-racing machines to compete against cars of more practical significance. This matter, it is realized, raises the old controversy as to what is a sports car. In endeavouring to assess the relative merits of the performances put up by the various designs, very many factors must be taken into account, and these could not reasonably be formulated in the rules governing a race. One of the most important factors of all is, of course, price, if it is agreed that the sports car should be regarded as a commercial proposition in ordinary series production. To the automobile engineer there are also the important matters that are bound up with the general balance of the design, the relating of engine size to passenger accommodation, general motoring amenities, and so forth. On these points in particular, the performance of a car that occupied third place before retiring after 21 hours, certainly merits commendation.

Another noteworthy performance was that of the Cadillac saloon which secured tenth place. This achievement will, it is hoped, check the tendency to disparagement of the technical quality and handling of the modern American car. It is not suggested that these vehicles conform precisely to the British ideal, but American designers have not, however, stood still. It is abundantly clear that the development work on independent suspension carried out in the U.S.A. on the ordinary car has been considerable. It clearly points the way to a more satisfactory suspension for high speed vehicles than has ever been envisaged by European sports car designers, with one recent and notable exception. That high speed controllability and discomfort must be inseparably associated, is a fallacy that dies hard. In this connection, it is high time that sports car designers cease to make a virtue of unnecessary vice.

Compensatory rating

To revert to the Le Mans event, broadly, everything depends on what is expected of these competitions. In a matter of this kind there will, of course, be many differing approaches. To the designer, however, one thing is clear, he will wish his machine to compete with others on terms as fair and equal as reasonable regulations permit. For this reason, and purely from the technical viewpoint, it is obviously unfair to pit ordinary production machines against racing cars without special measures of compensatory rating. There seems for instance, to be a definite need to make full and effective use of the production output figure. It is also obviously only fair that some account should be taken of the catalogue price. A realistic qualification, therefore, based on the number of cars made and sold, together with the cost to the ordinary buyer, would provide adequate protection against the infiltration of purely racing machines, and would do much to right the present unsatisfactory state of affairs.

Materials Handling

ALTHOUGH quite fortuitous, it is a happy coincidence that the Productivity Team's report on *Materials Handling in Industry* should appear just before the opening of the Mechanical Handling Exhibition recently held at Olympia. A visit to that Exhibition after a perusal of the report is instructive and enlightening. The most important point that emerges is that the range of British equipment for mechanical handling is as wide as the American. The wider use of mechanical aids in American industry cannot, therefore, be in any way attributed to the fact that they have a wider range of equipment from which to choose.

It does appear, nevertheless, that throughout industry generally, American engineers not only make greater use of mechanical equipment but they also study the problems of material handling much more thoroughly than is customary in this country. It is doubtful whether this applies fully to the British automobile industry. In fact, a perusal of the report suggests that in this respect our automobile industry has a standard as high as that prevailing in America.

Nevertheless, the automobile industry proper is dependent upon many other industries for supplies, and it is a common complaint that the cost of goods bought out, has risen to a much greater degree than the selling prices of motor vehicles. It is essential, therefore, that the auxiliary industries reduce their costs to something comparable with costs in the automobile industry. Several factors affect these costs, but there is no doubt that a closer study of handling problems and a greater use of mechanical handling equipment would lead to considerable reductions.

Most of the engineering factories in this country were built long before handling costs mattered, or there was any realization of the growing importance of materials handling as wages soared. It is almost inevitable that in certain respects, and particularly in the handling of incoming material, such factories must fall below the best level. Even so, closer co-operation between supplying factory and using factory, would lead to great improvement. The increased use of palletised unit loads is an obvious measure that could be developed without any great capital expenditure.

One very important point has emerged as a result of the productivity team visits, and that surprisingly enough, is the excellence of British standards.

The various reports issued by the several productivity teams that have visited the U.S.A. seem to be creating an impression that British industry lags far behind American industry. This is an impression that needs correction, and it should be placed on record that if the *average* British factory could be brought to something approaching the *best* planned British factory in any specific industry, Britain would be little if anything behind America.

What can be done in this country may be illustrated by two of the many developments that have been discussed in detail in this journal. For example, several years ago Humber, Ltd., modernized and mechanized their foundry to a most remarkable degree. This was described in detail in *The Automobile Engineer* for March, 1945. A more recent development in another field is the machining line developed by Vauxhall Motors, Ltd., for finishing cylinder heads for Bedford truck engines. This was described in *The Automobile Engineer* for May, 1950. These advances, and there are others like them, indicate that some British organizations with their production and planning engineers are fully alive to the importance of materials handling.

It now seems that working party or survey team visits to the more progressive British factories would be of greater value and of infinitely less cost than visits of productivity teams to the U.S.A. What these visits have shown, however, is that while the best in Britain is equal to the best elsewhere, the highest British standards are not yet sufficiently general throughout industry.

The Young Engineer

THE somewhat disjointed maxims that follow, are abstracted from a paper presented some little time back to the Society of Automotive Engineers by A. T. Colwell, Vice-President of Thompson Products Incorporated. Not all of these comments are original to Mr. Colwell, some are from other sources. All, however, are of a crisp and penetrating character. They crystallise some basic truth, of which all of us can occasionally be very suitably reminded. Of education he says "this is the knowledge of how to use all of ourselves." Many men use only one or two faculties out of the many with which they are endowed, yet an all-round development is essential to a full life, or a really useful personality.

Another factor is the all important one of enthusiasm on a job. This often counts as much as knowledge, because the job gets done. No man ever did outstanding work without this vital driving force. The man who is fired with enthusiasm for his work is seldom fired by the boss. Very often, particularly in research or development work, an executive will choose a man of good technical background even though he knows little about a given project, because he has enthusiasm and wants to try. The best progress is likely to be made by the man who does not know all the ways in which a thing cannot be done.

A reputation for accurate statement is an invaluable asset. Carelessness with facts is utterly inexcusable. Further, there is no discredit in saying "I do not know," provided that you immediately proceed to find out. The ability to express ideas clearly and easily is invaluable. Ideas are wanted, particularly if they are set out in explicit and understandable form. It is essential to be able to give clear direct answers to questions. The study of engineering of course is based upon analytical thinking. The whole of the engineer's technical life consists in fact of this type of thought. The ability to transmit this thought to paper, and in the form of short brief reports is valuable.

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THE JAGUAR XK120

A Super High-speed Car of Exceptional Controllability and Comfort

The Jaguar XK120 two-seater.

IN appraising the design, performance and handling of the Jaguar XK120, it is difficult to realise that the price is only £988. Moreover, although the car is described as a "super sports" vehicle, there is no doubt that the term is misleading in that it gives no hint of the true character of a car in which comfort, smoothness, and refinement are associated with an all-round performance substantially in excess of anything offered in a standard production vehicle.

It would be unfortunate if a flawless appearance, and the remarkable performance figures, among which may be noted a maximum speed in the neighbourhood of 125 miles an hour and an acceleration time from rest to 100 miles an hour of about 30 seconds, were allowed to obscure other qualities of more practical significance in everyday use. Of these, the suspension, sweet running, and flexibility would be quite outstanding in cars of much less performance and far higher price. Indeed it is in the suspension and steering that the car offers perhaps the greatest technical interest. Superb handling has been attained not by reason of any radical departure in layout, but on account of the excellent compromise that has been made in the control of a suspension relatively soft for the type of car. Accurate and decisive steering at high speeds is coupled with a lightness of touch right down to manœuvring conditions. The vehicle gives an impressive feeling of complete confidence and control that is apparent from the moment of first driving the car.

SPECIFICATION

ENGINE. Six cylinders. Bore and stroke 83 mm. by 106 mm. Swept volume 3,442 c.c. Maximum b.h.p. 160 at 5,200 r.p.m. Maximum b.m.e.p. and torque 140 lb. per sq. in. and 195 lb. ft. at 2,500 r.p.m. Compression ratio 7 : 1 or 8 : 1. Seven bearing crankshaft. Twin overhead camshafts driven by two-stage duplex roller chain. Twin S.U. carburettors.

CLUTCH. Borg and Beck single dry plate 10in diameter.

GEARBOX. Four speeds and reverse with constant load synchromesh on top, third and second. Ratios : top, 1 : 1 ; third, 1·367 : 1 ; second, 1·982 : 1 ; first and reverse, 3·375 : 1.

REAR AXLE. E.N.V. banjo type with hypoid gears. Alternative ratios 3·27, 3·64, 3·92, 4·3 or 4·56 to 1.

SUSPENSION : Front—wishbones and torsion bars with anti-roll bar. Rear—semi-elliptic springs in conjunction with Hotchkiss drive.

BRAKES. Lockheed hydraulic, two leading shoe at the front. Brake drum diameter and effective width 12in × 2½in. Friction area 207 sq. in.

TYRES. Dunlop Road Speed 6·00—16. Pressed steel wheels, five stud mounting.

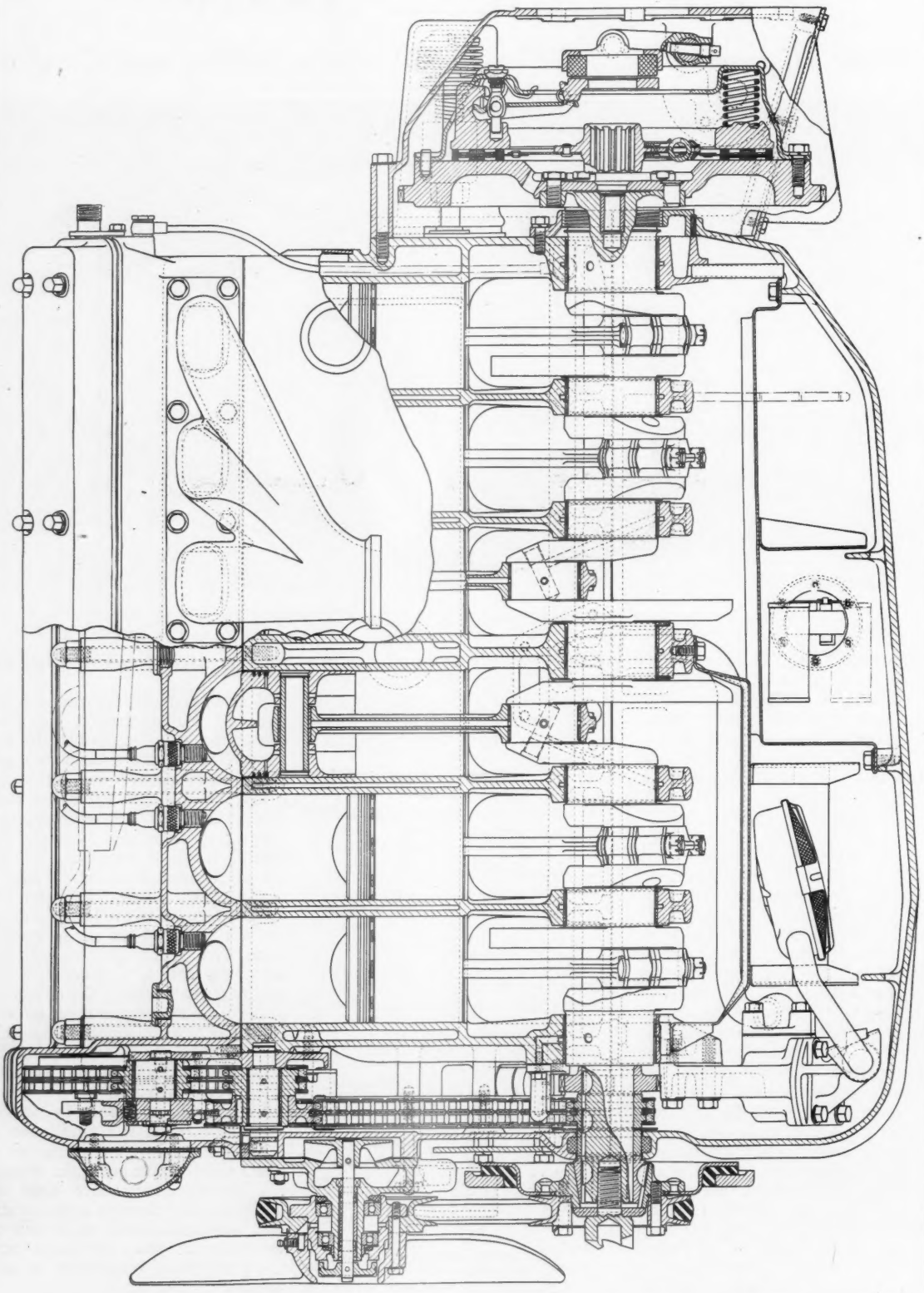
DIMENSIONS. Wheelbase 102in. Track—front 50⅜in at ground, rear 50in. Turning circle 31ft. Ground clearance 7⅛in. Weight, dry, 2,800 lb.

Without restating the case so often made in the *Automobile Engineer* concerning the contribution to the improvement of the automobile made by the pure racing car in recent years, it may be said that soft suspension, light steering and a pronounced understeer characteristic constitute the general trend in essentially touring car development over the last fifteen years. These characteristics are admirably blended in the Jaguar XK120 and the record of the car in competition, even at this early stage in the life of the design, is evidence of the quality of the vehicle. The behaviour of the car in this respect is not inferior to that of vehicles designed on what may be called the classical sports car principle, in which comfort is sacrificed to controllability.

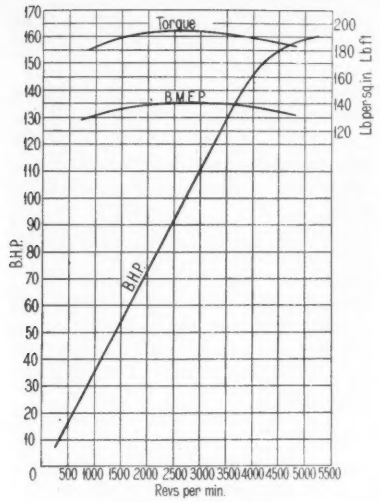
This excellent balance in suspension and steering is a vindication of the logical process of development in which the desirable principles of touring car suspension have been coordinated and refined to a point where safe and comfortable travel can be maintained at speeds well beyond anything at present conceivable in daily transport.

It is the more surprising therefore that the Jaguar chassis should be so entirely orthodox in conception and

THE JAGUAR XK120 (Continued)



LONGITUDINAL SECTION OF JAGUAR XK120 ENGINE. Bore and stroke 83 mm. x 106 mm.



Performance curves.

layout, and upon superficial examination exhibits nothing that would suggest unusual performance. There is, however, much evidence of great care and judgment in detail design, and doubtless it is here that the reasons must be sought for the quite exceptional character of the car. It is in fact so good, that some restraint is necessary in describing its charm. Without indulgence in too many superlatives, however, it must be admitted that the advent of a vehicle of this kind in which *all* the desirable attributes are combined, is something of an event. From nowhere else in the world is such a car forthcoming, and the prestige of British industry is correspondingly raised.

Engine

The six-cylinder engine has a bore and stroke of 83 mm. by 106 mm. (3·27in by 4·17in), giving a swept volume of 3442 c.c. (210 cu in) and a piston area of 50·4 sq in. A compression ratio of either 7 to 1 or 8 to 1 is employed and with the 8 to 1 ratio the maximum b.h.p. is 160 at 5,200 r.p.m. while the maximum b.m.e.p. and torque is 140 lb per sq in and 195 lb ft at 2,500 r.p.m. The dry weight of engine and gearbox is 640 lb, of which the gearbox accounts for 110 lb.

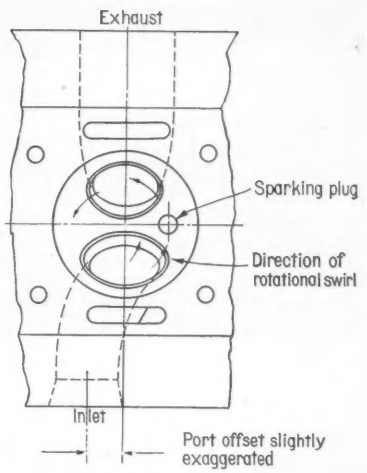
Made in chrome cast iron, the cylinder block and crankcase forms an integral unit extending down to the crankshaft centre-line, the seven main bearing housings being not only well ribbed vertically, but also tied to the crankcase wall by fillets of generous radius, as shown in the illustration. There are full length water jackets with a separate gallery along the near-side, into which the water pump delivers directly. Water spaces are provided between adjacent bores. The cylinder bores are machined with a single point tool and finished by honing.

Each main bearing cap is secured by two $\frac{1}{2}$in diameter bolts and located by two dowels. A circumferential oil groove in the caps and housings is provided for distribution of the feed behind the bearing shells, which are of Vandervell steel-backed white metal type, having single circumferential oil grooves with two feed holes in each half bearing. The main oil gallery and cross feeds to the main bearings are formed by drillings in the casting.

Of En.16 manganese molybdenum steel, the crankshaft, which is, of course, statically and dynamically balanced, has journal diameters of 2·75in and crankpin diameters of 2·088in. The effective crankpin length is 0·97in, while the journals have the following effective lengths: front, centre and rear 1·5in, intermediate 1in. Crankshaft end thrust is taken by steel-backed white metal strips carried on each face of the centre bearing.

Behind the rear main bearing is an oil flinger and return thread, the crankshaft terminating in a flange to which the flywheel is attached. The clutch spigot bearing is of porous bronze. A separate split housing surrounds the return thread, the upper part being secured to the rear face of the cylinder block, while the lower part, located by two dowels, forms a joint with the sump.

Beyond the front main bearing the crankshaft carries the oil pump and distributor drive skew gear, the camshaft drive sprocket, an oil thrower, a sealing collar, and a taper sleeve on which is mounted the Metalastik bonded rubber, torsional vibration damper to which is also attached the fan pulley. These individual components at the front of the crankshaft are located by single Woodruff keys with the exception of the damper mounting cone, which has two Woodruff keys. The whole assembly is pulled up against the front journal by means of a washer behind the starting handle dog and the oil seal is formed by graphited asbestos housed in the crankcase and sump.

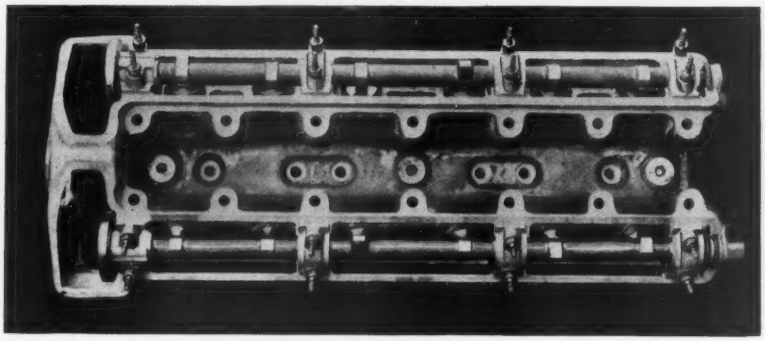


Plan of inlet and exhaust ports.

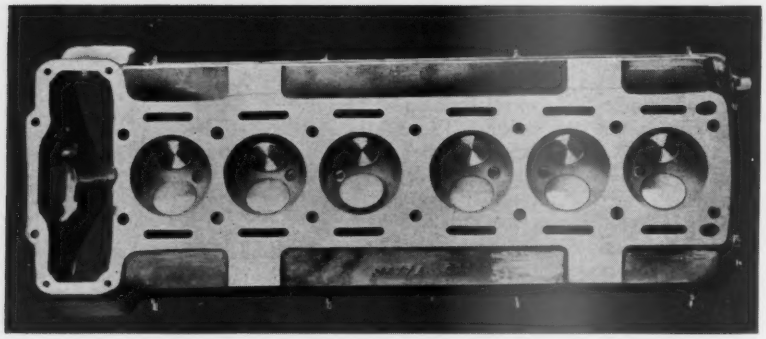
Diagonal drillings from the journals lead to $\frac{29}{64}$in diameter blind bores in the crankpins. The feed to the big-ends is by means of a transverse hole drilled right across the pin so that in effect there are two feed holes. Since these holes are well inside the maximum radius described by the crankpin bores, an effective sludge trap is provided that would be unlikely to interfere with the oil flow to the bearing.

Made in En.16 the connecting rods have a centre distance of 7·75in and the single ribbed caps are located by fitted bolts. Oil is fed to the small end through a $\frac{3}{16}$in diameter drilling. As in the case of the main bearings, the big-end bearings are of Vandervell steel-backed white metal type.

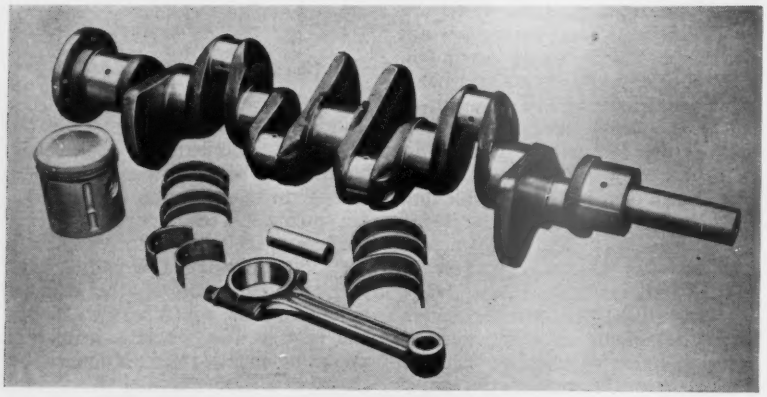
The Aerolite aluminium alloy solid skirt pistons are tin-plated and each carry two compression rings



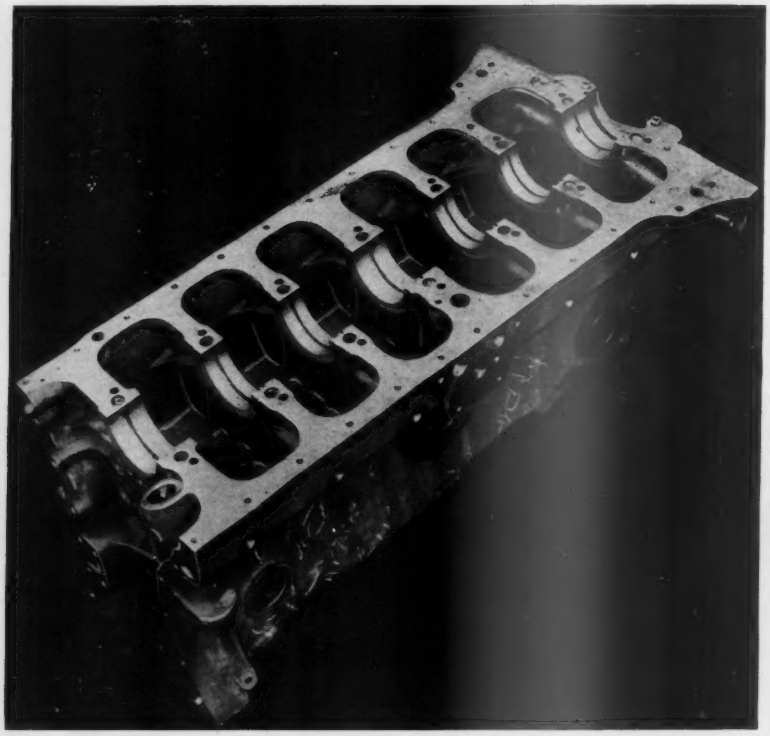
Cylinder head with camshafts in position.



Cylinder head showing combustion chambers.



Piston, connecting rod, crankshaft and bearings.



Cylinder block and crankcase showing main bearing housings.

and one slotted scraper ring, the upper ring being chromium plated. Fully floating gudgeon pins made in case-hardened steel are $\frac{7}{8}$in. in diameter and are located by internal circlips.

Secured to the cylinder block by fourteen $\frac{3}{8}$in diameter waisted studs, the cylinder head is of aluminium alloy in RR.50. In addition to the main studs there are six smaller studs securing the front end of the head. The combustion chambers are approximately hemispherical and the general design of the valve ports, induction system and combustion chambers has been carried out in collaboration with Weslake & Co., Ltd.

The accompanying illustration shows the port layout in which the off-set of the inlet port has been slightly exaggerated. Control of turbulence is brought about by the curved sides of the inlet port and the degree of swirl can be controlled by an increase or decrease in the rate of curvature of these walls.

It will be seen that the port entry is tapered to increase the velocity of the charge from the induction pipe and to produce a piled effect by making use of the kinetic energy of the charge. This first zone is followed by a second zone around the valve guide shaped to decrease the obstruction caused by the guide. The third zone is the inlet valve seat which has a radiused entry to the valve seat proper. This, in conjunction with the valve shape, gives the highest possible flow at low valve lift.

It is claimed that the control of turbulence provided in this engine permits the burning of lean mixtures and over the normal speed range of the engine at 75 per cent full load the fuel consumption need not exceed 0·47 pints per b.h.p. hour and at 50 per cent load, 0·52 pints per b.h.p. hour. Under full load conditions the maximum power fuel consumption is between 0·5 and 0·53 pints per b.h.p. hour and an economy setting giving 0·47 pints per b.h.p. hour can be used with some loss in brake mean effective pressure.

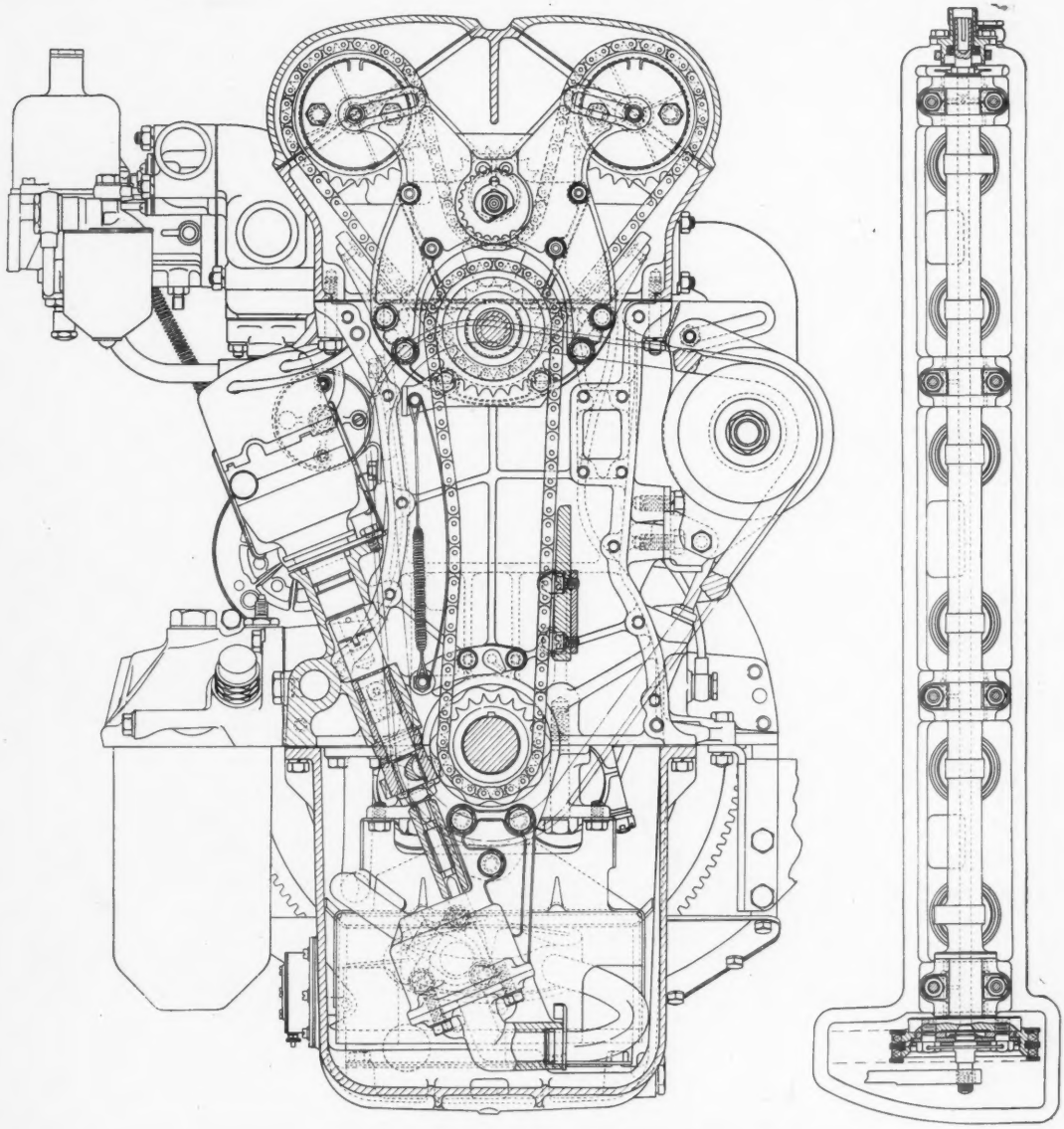
The valves are set at an included angle of 70 deg and are operated from twin overhead camshafts by cylindrical tappets made in chill cast iron, with tappet bearings also of cast iron and a shrink fit in the cylinder head. The valves seat on Brimol inserts shrunk in by heating the head in oil. The seat angles are 30 deg for the inlet and 45 deg for the exhaust. The inlet valves are of En.52 silicon chrome steel and have a throat diameter of $1\frac{3}{8}$in and a lift of $\frac{5}{16}$in, whereas the exhaust valves are in Fox 1282 austenitic steel and have a throat diameter of $1\frac{1}{4}$in and a lift of $\frac{5}{16}$in.

built up from the two discs forming an adjuster plate having a central guide pin that projects through a slot in the idler support bracket and terminating in a threaded end. The sprocket rim spigots on to the camshaft flange and has internal serrations in the bore of its own shallow flange. These engage serrations on the periphery of one of the discs forming the adjuster plate, while the second disc, of larger diameter, rests against the front face of the rim flange and is retained there by means of an internal circlip. The two setscrews, by means of which the sprocket assembly is secured to the camshaft flange, pass through clearance holes in the adjuster plate.

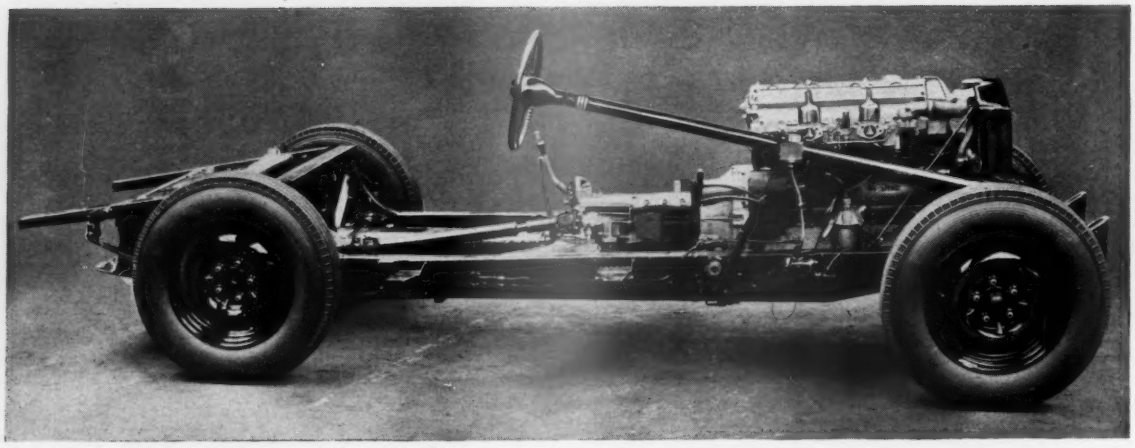
To set the valve timing, No. 1 piston is brought to top dead centre on the firing stroke and the camshafts are turned until keyways formed in their flanges behind the front bearings engage with tongues in setting gauges. The sprockets, with chain in position, are placed on the camshafts and the adjuster plates are withdrawn until the serrations disengage. The plates are then rotated until their holes for the set pins coincide with the tapped holes in the camshaft flanges. After re-engaging the serrations and installing the circlips the set pins are inserted and locked with wire.

It should be noted that removal and replacement of the cylinder head is carried out without disturbing the valve timing. It is only necessary to slacken the chain adjuster, remove the set pins from the sprockets, withdraw the sprockets from the camshafts and slide them along the slots in the brackets. After placing clamping nuts on the guide pins to hold them in the slots, the head can be removed. The adjustment of chain tension and valve timing will be evident from study of the illustrations.

Driven from a skew gear at the front end of the camshaft is the distributor and oil pump drive shaft. The gear-type oil pump draws oil from the DTD.424 die cast sump through a floating inlet and delivers through a separate pipe to the Tecalemit full flow filter where the relief valve is also accessibly placed. From here the oil enters the main gallery drilled along the offside of the crank-



Arrangement of camshaft drive and sprocket assembly.



Off-side view of XK120 chassis.

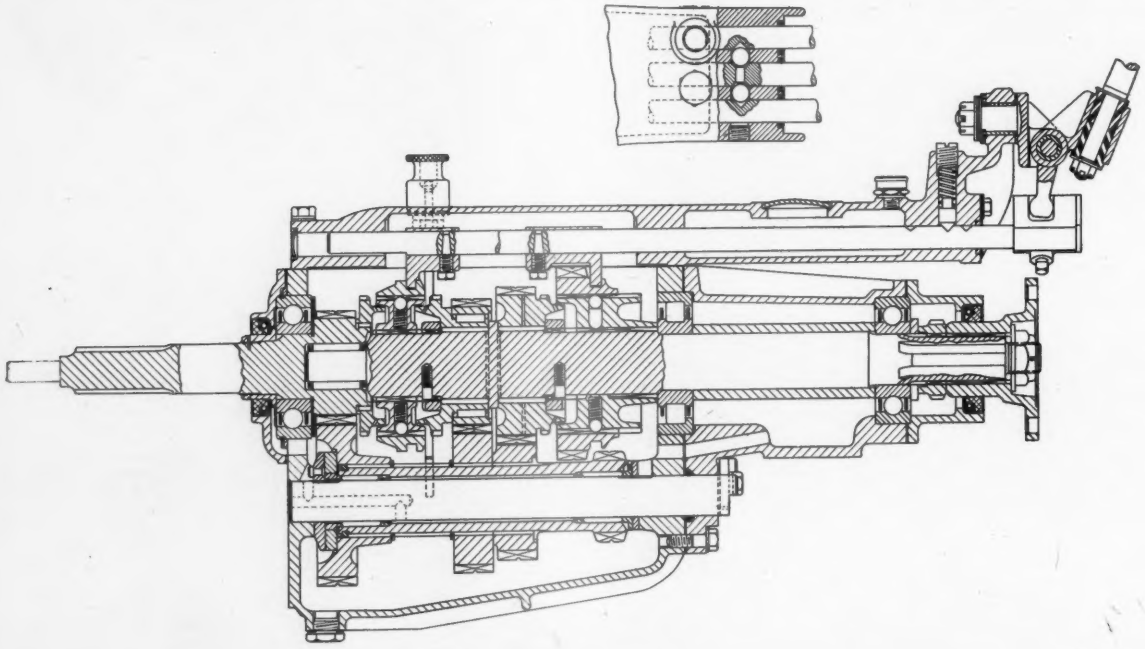
case and is fed through transverse drillings to annular grooves in the main bearing housings and caps, from which it feeds into the bearings through four holes in the bearing shells. Thence the oil passes through the crankshaft drillings to the connecting rod big-ends and so to the small ends via the drillings in the connecting rod shanks. A continuation of the cross drilling to the rear main bearing feeds an external pipe on the near-side of the engine by means of which oil is led to the rear camshaft bearings. From here it feeds into longitudinal drillings in the camshafts, from which appropriate cross drillings in the journals provide a feed to each camshaft bearing.

The cams dip into the overflow from the bearings and the oil returns to the crankcase from the front end of the head, flooding the upper camshaft drive chain. The intermediate and idler sprocket spindles are drilled longitudinally and transversely to provide an oil feed to the sprocket bushes. Oil returning from the cylinder head is collected in troughs formed in the idler brackets and feeding the spindle drillings via drillings in the bracket. Lubrication of the first stage chain is provided by jets fed from a drilling leading off the oil supply to the front main bearing. A jet is also provided here for the oil pump and distributor drive skew gears. The sump capacity is 24 pints.

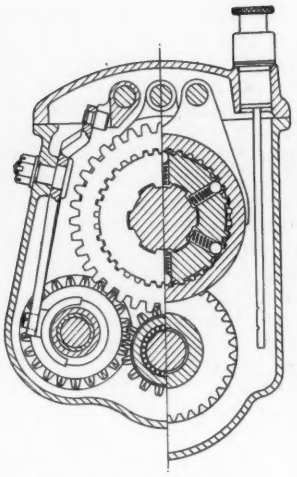
Cooling system

Water from the pump is delivered to a gallery running along the nearside of the cylinder block from which passages into the head direct water around the faces of the combustion chambers and across to the off-side of the head past the sparking plug bosses. The water emerges through four holes along the off-side face of the head into the induction manifold jackets, from which it finally returns to the header tank. It will be evident that the forced circulation is confined to the cylinder head and induction manifold, while the water surrounding the cylinder bores remains relatively undisturbed.

The induction manifold has a full



Arrangement of gear box.



Gear box cross section.

length water jacket along its top face and there is a shorter jacket along the bottom face under Nos. 3 and 4 ports. There are also water pockets formed between Nos. 1 and 2 and 5 and 6 ports on the inner side face of the manifold.

The water pump spindle driven by the fan pulley, which is carried on two ball bearings, has a synthetic rubber seal. At the rear end separate greasers are provided for the ball bearing and spindle. A by-pass thermostat is embodied in the system.

Ignition

Ignition is by Lucas coil and distributor and Champion type NA8 14mm sparking plugs set with gaps of 0·022in. The distributor has centrifugal and vacuum advance and the timing is set at 5 deg before top dead centre fully retarded, with the vernier adjustment in the midway position. An advance range of 11 to 13 deg on the distributor is provided by the vacuum system while the centrifugal advance mechanism has the following characteristics:—On engines of 7 to 1 compression ratio the advance range on the distributor is 16 to 18 deg with full advance at 1,400 r.p.m. On 8 to 1 compression ratio engines the advance range is 13 to 15 deg on the distributor with full advance at 1,600 r.p.m.

An S.U. electric petrol pump supplies the twin horizontal S.U. carburettors, which have a bore of 1¾in. There is also an auxiliary starting carburettor with automatic thermo-electric operation.

The aluminium alloy induction manifold is of the six-port type with the induction tract of rectangular section. Midway along the tract is a balance restriction having a circular hole, and at this point the mixture from the starting carburettor is delivered.

Clutch

Enclosed in a DTD.424 aluminium alloy bell housing, the clutch is a single plate Borg and Beck unit with 10in diameter disc and conventional carbon block type of withdrawal bearing.

Gearbox

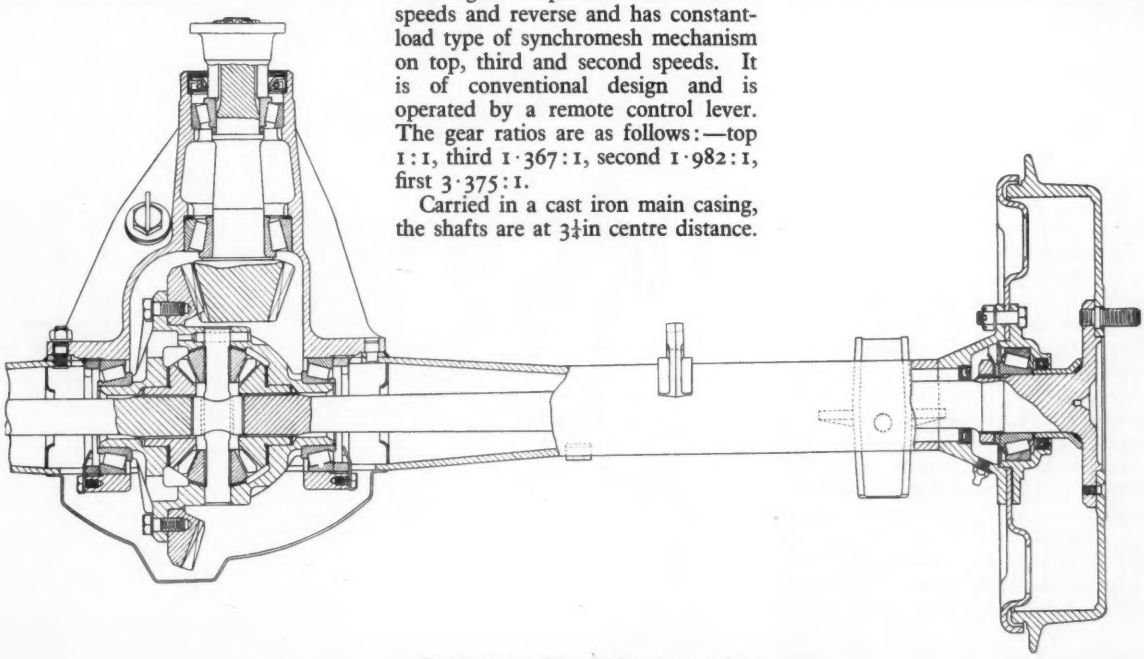
The gearbox provides four forward speeds and reverse and has constant-load type of synchromesh mechanism on top, third and second speeds. It is of conventional design and is operated by a remote control lever. The gear ratios are as follows:—top 1:1, third 1·367:1, second 1·982:1, first 3·375:1.

Carried in a cast iron main casing, the shafts are at 3¼in centre distance.

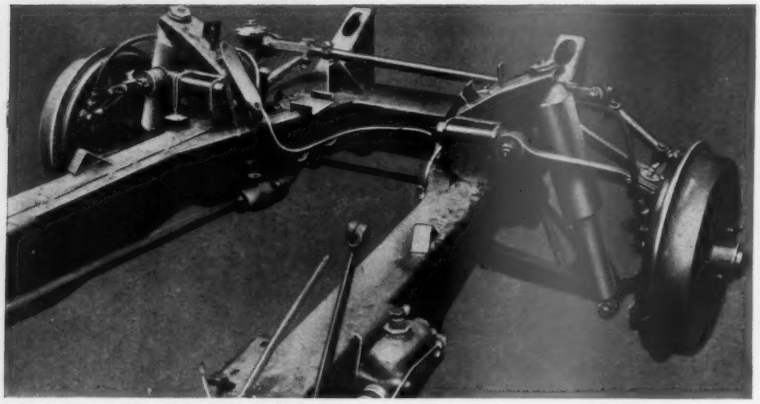
Rear anchorage of torsion bar.

A light alloy casting encloses the rear end of the mainshaft which extends for a distance of about 8in behind the roller bearing in the gearbox main casing. Its outer end is supported by a ball bearing in the extension casing, while the spigot bearing in the first motion shaft bore is of the needle roller type. Needle rollers are also employed to support the third and second speed mainshaft gears. Both the first motion shaft and constant pinion and the mainshaft are in Fox 040 Hicore 90 steel, as is the layshaft with which is formed the first speed pinion. All other gears are also in Fox 040.

The dog rings and operating sleeves are in Fox 031 Hicore 75 and it is of interest to note that the synchromesh sleeves in En.36 have no bronze facings. The cone included angle is 10 deg. and the oil grooves on the dog rings consist of thirty-six axial grooves 0·04in wide and 0·02in deep, and a right-hand thread of 0·02in pitch,



Arrangement of hypoid bevel rear axle.



Rear view of front suspension.

0·009in deep, 0·01in wide at the top and having an included angle of 42 deg. The gears have a diametral pitch of 10 circular, equivalent to a normal D.P. of 10·86, a 20 deg. pressure angle, and the constant mesh third and second speed gears all have a right-hand helix angle of 23 deg. The face widths are as follows:—constant mesh and third speed gears 1in, second speed gears 31/32in, first speed gear $\frac{13}{16}$in. Needle roller bearings support the layshaft assembly with end location by means of chill cast phosphor bronze thrust washers butting against thrust pads of En.36T normalized. There are no unusual features in the selector mechanism, which has die-cast aluminium bronze forks and interlocking of the selector rods by means of two balls and a plunger, as shown in the arrangement drawing.

Rear axle

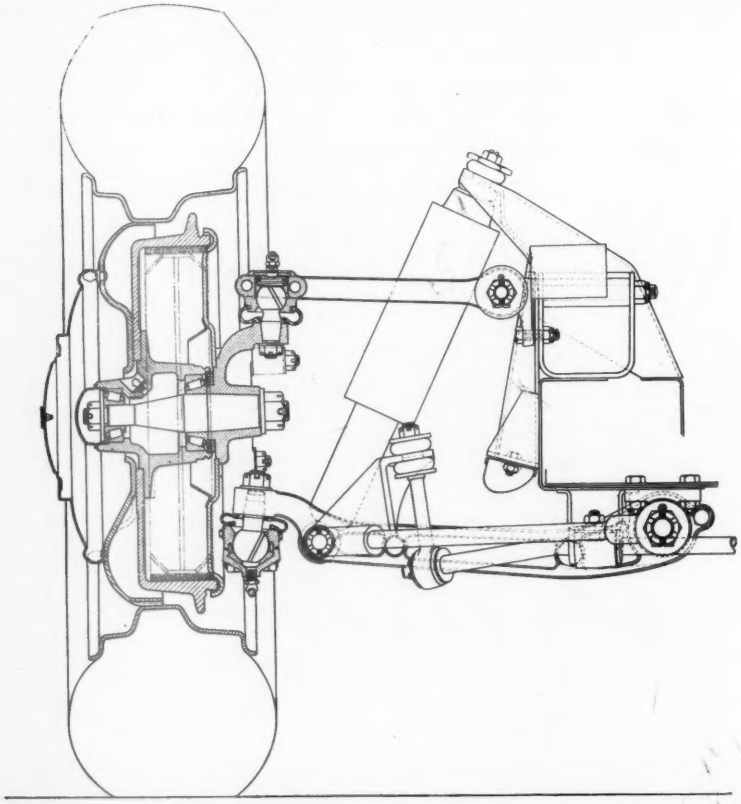
Alternative ratios are available in the E.N.V. hypoid bevel rear axle, namely 3·27, 3·64, 3·92, 4·3 or 4·56 to 1. The axle is of the banjo type with semi-floating shafts made in En.19 and tapering from 1in diameter behind the splines to $1\frac{3}{8}$in diameter at the inner oil seal. The outer ends of the shafts are up-set to form the brake drum and wheel mounting flanges which carry five $\frac{1}{2}$in diameter wheel studs. Both the main gear casing and the differential cage are made in Lepaz malleable iron, while crown wheel and pinion are made in En.34 and En.35A respectively. The two-pinion differential has En.33 pinions and gears, while the spider is in 3S 15. The inner ends of the axle shafts butt against a thrust block and the taper roller hub bearings are shimmed between the bearing housing and brake back plate to give 0·002-0·004in axle shaft end play. Adjustment of the differential taper roller bearings is by means of ring nuts, while the pinion shaft, which is also carried in taper roller bearings, is provided with shims behind the outer race of the inner bearings.

Suspension

Before treating the front and rear suspensions individually, it may be of interest to consider the suspension as a whole and its influence on the handling characteristics of the car. Table I shows the relative characteristics, and it will be seen that the front suspension is somewhat softer than the rear. The front/rear weight proportion is 45·5/54·5 per cent, based on a loading of driver and passenger, oil and water but no petrol.

The general layout is designed to result in a condition of under-steer and to this end the anti-roll bar is fitted on the front suspension and the rear springs are inclined downwards towards the front at an angle of $7\frac{3}{4}$ deg. At the front the roll centre is within $\frac{1}{2}$in of ground level, while the height of the rear roll centre is about $9\frac{1}{4}$in. The height of the centre of gravity of the sprung mass is about 18in, giving a moment arm about the roll axis of 13in. The height of the centre of gravity of the unsprung masses, that is to say, the front wheels and suspension linkage, and also the rear axle, is $13\frac{1}{2}$in.

The roll stiffness of the front suspension is 6,050 lb in per deg, and of the rear suspension 1,730 lb in per deg, giving a total roll stiffness of 7,780 lb in per deg. Taking a lateral acceleration of 1·0g for convenience, the resultant roll angle is 5·1 deg, and the total roll transfer on the front tyres is 606·5 lb, made up of 561 lb due to the sprung mass and 45·5 lb due to the unsprung mass. The total roll transfer on the rear tyres is 529·5 lb, made up of 162·5 lb due to the

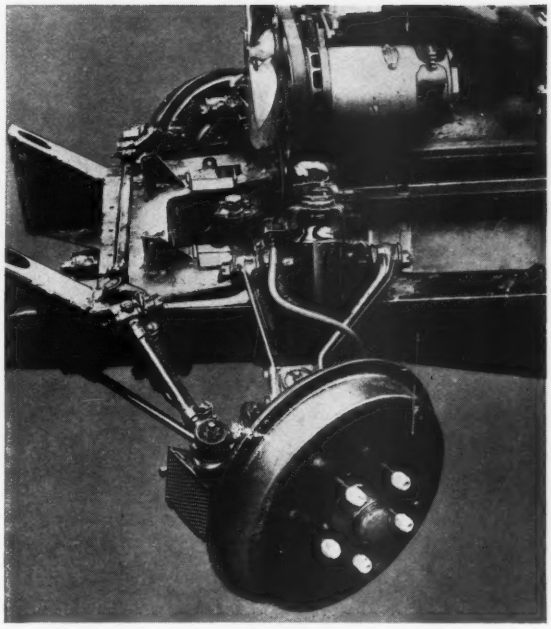


Elevation of front suspension.

TABLE I

	Front	Rear
Total weight per wheel ..	710 lb.	845 lb.
Unsprung weight per wheel	110 lb.	155 lb.
Sprung weight per wheel ..	600 lb.	690 lb.
Effective static deflection ..	5½in.	5in.
Nominal frequency* ..	80 oscillations per minute.	84 oscillations per minute.
Static stress in spring ..	56,500 lb. per sq. in.	88,000 lb. per sq. in.

* These figures take into account the effect of the rubber bushes in the suspension linkages.

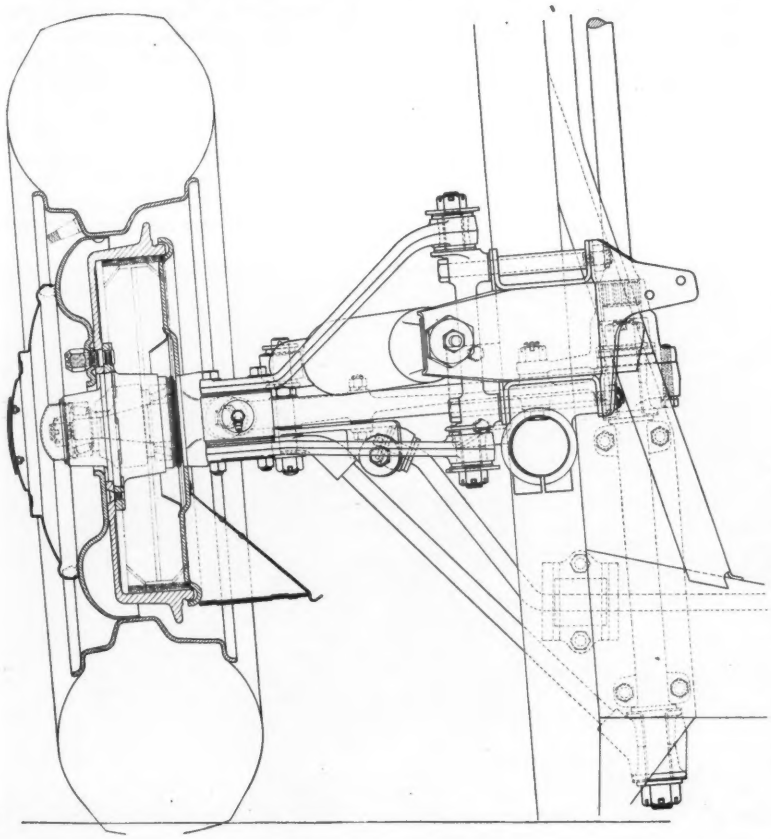


Front suspension and track rod layout.

moment of the sprung mass about the roll axis, 270 lb due to the side thrust of the sprung mass operating at the rear roll centre, 84 lb due to the rear unsprung weight and 13 lb due to the front unsprung weight.

It is of interest to note the contribution made by the anti-roll bar. Thus the front suspension rate in rolling is 265 lb per in, while the rear suspension rate in rolling is 138 lb per in. The stabilizer rate is 150 lb per in and the force transfer due to the stabilizer amounts to 345 lb out of the total front transfer of 605·5 lb.

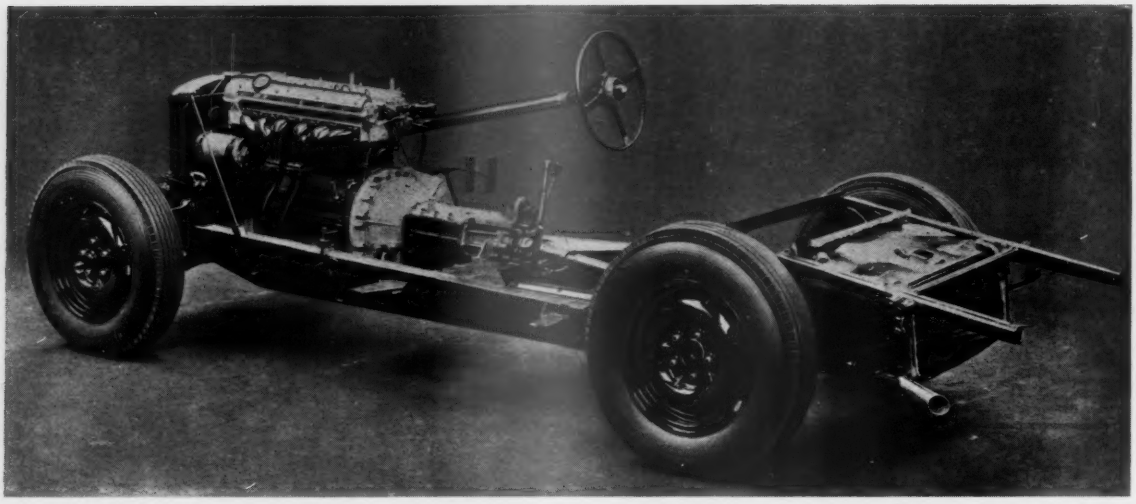
In normal circumstances the high proportion of the overturning couple carried by the front tyres should ensure that the self-aligning torque is adequate without the assistance of any appreciable castor angle. However, to meet conditions of sustained high speeds, it is necessary for satisfactory tyre life to increase the normal tyre pressures of 25 lb per sq in to 35 lb per sq in. This substantially reduces the self-aligning torque and in fact a castor angle of 3 deg is provided. This might be expected to result in rather heavy steering when normal tyre pressures are employed, but in practice the effect is not noticeable. Doubtless the reason may be found in the high efficiency of the Burman re-circulating ball type of steering gear, and also in the design of the stub axle swivel joints, which are spherical joints having a spread of about 8⅞in and probably result in appreciably less friction compared with more conventional designs.



Plan of front suspension.

Front suspension

Torsion bars in conjunction with wishbones form the basis of the independent front suspension, which has a total movement of 7in made up of 3½in bump and 3½in rebound. Damping is provided by Newton direct acting dampers and the inner wishbone pivot points each have opposed Metalastik BC type conical bonded rubber bushes. Each wishbone is made up of two separate arms, the upper assembly having an effective length of 8¾in with a spread at the inner end of 7¾in. The two separate wishbone arms in En.8Q are bolted together at their outer extremities with the upper ball housing interposed. The lower wishbone assembly comprises a rear member of I-section in En.16T to which is bolted the internally splined torsion bar flange. The lower front wishbone lever or stay rod in mild steel is of circular section ⅝in diameter and is bolted to the rear member at a point adjacent to the outer end. The spread of the inner lower wishbone

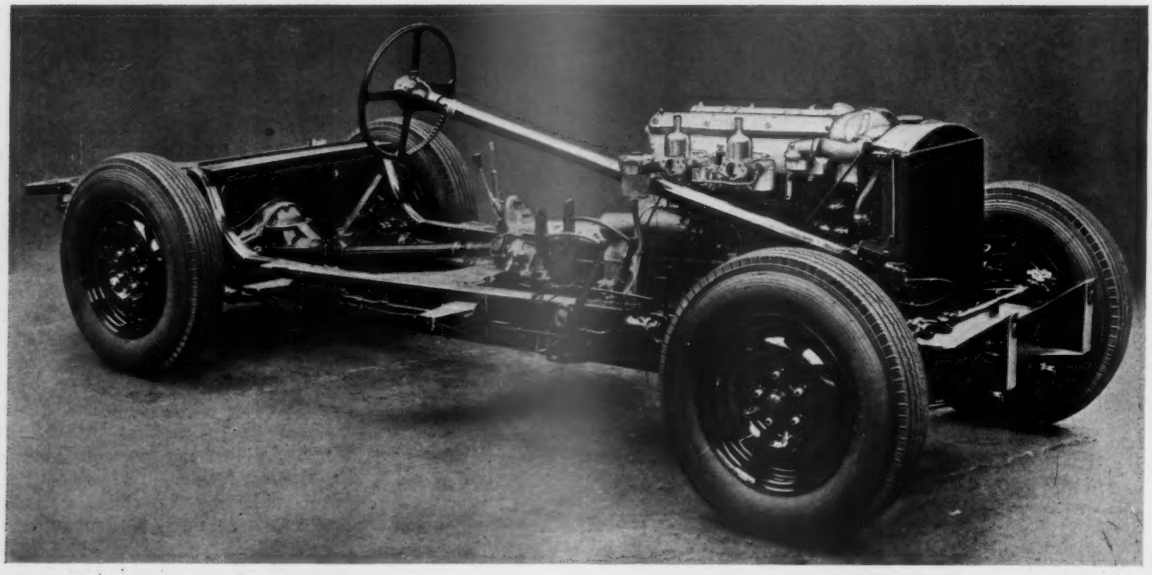


Three-quarter rear view of chassis.

bearings is 13in and the effective length is 15in.

The screwed pin connecting the lower wishbone levers at their outer ends is extended rearwards to form the attachment point for the lower end of the damper, where there is a rubber bush, while a bracket carrying the connecting link to the anti-roll bar is also partly located off the same pin. The lower wishbone terminates in a taper seating for the lower ball pin which, as in the case of the upper pin, is made in En.24T. The lower ball pin, which is hard chrome plated, seats on spherical seatings made in Ferrobestos LA3, an asbestos and plastic material impregnated with graphite. Whereas the upper ball housing embodies spring loading of the spherical seating, the lower ball socket has a cap attached to the stub axle carrier by means of four set-screws and located by a spigot ring with shims interposed between the socket cap and stub axle carrier. The En.16T stub axle shaft is located in the En.16T stub axle carrier by means of a taper and locknut and carries the Timken taper roller hub bearings. The hub itself is in Ley's blackheart malleable iron. A castor angle of 3 deg is provided, with adjustment by means of shims interposed between the upper wishbone arms and the ball housing. Camber is also adjustable by means of shims interposed between the upper wishbone shaft and the frame bracket, the normal setting being $1\frac{3}{4}$ to 2 deg. The effective swivel centreline inclination is 5 deg.

Made in En.45 silico manganese steel ground bar by the English Steel Corporation, the torsion bars have a working length of 47·25in and a diameter of 0·930in. They are shot peened, pre-stressed in the direction of twist and finished with a coat of protective "flexible" paint. The ends of the bars are splined and locate at the front end in flanges bolted to the rear lower wishbone members. At their rear ends the torsion bars locate in the splined bores of reaction levers, the forked ends of which bear on thrust pads and adjusting nuts carried by long bolts, the heads of which seat in the centre cross member. Clockwise rotation of the adjusting nuts increases the ground clearance and *vice*



Three-quarter front view of chassis.

AGRICULTURAL TRACTORS

An Indication of the Trends in the German Industry

AN article in the February number of the German journal *ATZ* by Dr. Ing Arthur Seifert gives an interesting picture of the present position of the German agricultural tractor industry. The author begins by deploring the absence, from a Show in Hanover in August, 1949, of any four-wheeled tractors suitable for the small farmer. There are, of course, the small single-axled machines with integral cultivators, etc., these being available in many varieties in Germany as in this country, and having engines of power ranging from 1½ to 6 h.p.

The standard tractor in Germany, as in this country, has an engine of about 25 h.p. and a running weight of about 30 cwt. In England this category would include the Fordson Major, the David Brown tractor, the Nuffield and the Field Marshall, with the Ferguson as a rather special case, as being intentionally made as light as possible for use with directly attached implements.

In the opinion of the author there is a wide field for four-wheeled tractors of about 15 h.p., not merely for market-garden and row-crop cultivation, but for all the operations usually carried out on a small mixed farm. Whatever the views of English farmers and manufacturers may be, it is clear that the German tractor industry is in agreement with him, for, at a show held in Munich at the end of 1949, eleven firms were showing new tractors coming in this category.

There were 32 different tractor firms exhibiting and 66 different types were on view. This would seem to indicate over-development, and small-scale building likely to be uneconomic, in spite of the fact that many were "assembled" products. Proprietary engines and complete transmissions are made by several concerns. No mention whatever is made of petrol or paraffin engines, which were apparently absent, all motors described being of the compression-ignition type.

The tractors in the 25 h.p. class, generally had two-cylinder vertical engines, though one three-cylinder type was shown. In the 15 h.p. class single-cylinder engines were the rule, with the exception of a two-cylinder 16 h.p. water-cooled vertical motor developed by the Güldner concern. Four-stroke operation was usual, though among the proprietary engines there was a horizontal two-stroke with hopper cooling, made by the firm of Hatz. This engine has a cubic capacity of 1.02 litres and gives 12 h.p. at 1,500 r.p.m.

Water-cooling is almost universal but there are three new examples of air-cooling, a 12 h.p. air-cooled two-stroke by Stihl, of Neustadt, a single-cylinder 16 h.p. four-stroke by Eicher, of Forstern, and a 28 h.p. twin-cylinder four-stroke developed by Deutz from the components used on the existing four-cylinder and six-cylinder engines.

In the Stihl tractor electric starting is provided and the complete machine weighs only 1,600 lb, but the Eicher engine is intended for hand starting and has a very heavy flywheel. Partly as the result of this the complete machine weighs about 30 cwt.

The Eicher engine has a centrifugal cooling blower, whereas the two-cylinder Deutz has an axial-flow blower with die-cast guide-vanes on the inlet side. The Deutz, which has a capacity of 2.6 litres, employs a swirl-chamber of cast-iron made integral with the aluminium cylinder head.

It is understood that Deutz are developing a single-cylinder 16 h.p. engine also. This will be fitted with a thermometer and control of the cooling-air inlet. The fan horse-power is given as 6.5 to 7 per cent of maximum.

The ante-chamber construction is rapidly giving place to the whirl-chamber system with various modifications to assist starting. In the 1.56-litre single-cylinder Schlüter engine the chamber is movable, to allow the spray to strike direct into the cylinder when starting. In the three-cylinder 28 h.p. Primus, part of the spray always strikes direct, the arrangement being similar to that employed on the Perkins engine in this country.

It is stated that the abandonment of the ante-chamber has also resulted in reduced fuel consumption. Since the average power used in many agricultural operations is only about 40 per cent of the maximum, consumption has been improved by some firms who fit adjustable governors. The user is recommended to use a high gear and a low engine speed where possible.

Most of the single-cylinder engines are distinctly heavy, the air-cooled Eicher engine, for example, which gives 16 h.p., weighs 740 lb. The two-cylinder 28 h.p. Deutz only weighs 770 lb and is much lighter on a horse-power basis. The three-cylinder Primus water-cooled engine gives 28 h.p. and, with a capacity of 2.9 litres, develops its rated power at 1,500 r.p.m., the weight being 1,100 lb.

There has been no change in the position with regard to the withdrawal of overtime working by a section of the printing industry. A slight reduction in the number of pages in *The Automobile Engineer* continues to be unavoidable. All journals printed in London are similarly affected, to a greater or lesser extent, but journals printed in the provinces are not affected.

Entry into the tractor industry is for many much facilitated by the availability of complete transmissions, from bell-housing to back wheels. These components are made by the well-known ZF concern and a gear-cutting firm in Augsburg among others. Five speeds are normally offered and, in some cases, the lowest gear is a "crawler" speed of about ¾ mile an hour. The more common ratios cover from 1.8 to 11.5 m.p.h.

ZF offer a portal axle, with final drive by spur gears, giving big ground clearance for row-crop cultivation. Power take-offs often give two speeds, 510 and 810 r.p.m. Provision is also made for four-wheel drive if required, while the drive for an attached mower blade is in some cases by "V" belt from a countershaft that also drives the tyre pump.

Power lifts for implements have not been developed as fully as might be expected, partly because of cost and also because the special implements are not yet widely available. One firm offered pneumatic operation while another employs an electric starter motor for lifting with a hand-lever controlled brake for lowering. The lifting motor switch button is conveniently located on the end of the hand-grip. Direct hand operation is relied on for some of the mower attachments, while one ingenious machine, largely built from Jeep parts, employs a power-operated screw for the lifting gear, this having automatic knock-off at each end of its travel.

This tractor, known as the Alpenland, has rear-wheel drive but four-wheel steering, the rear wheels having only about one-third the lock of the front ones. One advantage claimed for this somewhat complicated construction is that the neutral point of the turning circle comes well behind the back axle. An attached implement is not, therefore, subject to lateral displacement when turning, and not so likely to damage root crops when turning at the end of a row. The machine only weighs 1,000 kilogrammes (say one ton), but when coupled to a special trailer the adhesion can be increased by transferring some of the trailer weight to the driving axle.

To attain this end, the trailer drawbar fits closely into the tubular arm of the power-operated lifting gear and is secured by a pin. Movement of the arm actually raises the front wheels from the ground, so that their weight, plus some of the weight of the trailer, is available for adhesion. The small lock provided for the back wheels is quite adequate for steering, because the wheelbase of the rigid unit formed by the tractor back axle and the trailer front axle is exceedingly short.

H

MATERIALS HANDLING*

Methods, Motion and Time Studies

By W. James Webb, A.M.I.Mech.E., A.M.I.P.E., A.M.I.I.A.

IT will be appreciated that in any enterprise engaged in the manufacture, processing or distribution of commodities essential to modern civilization, we are at once faced with three fundamental elements—*method, motion* and *time*. The intimate balance of these elements determines output, production cost and, finally, the purchasing power of wages. For most of us this may be translated into the standard of living we can enjoy.

Fundamental conditions

There can be no controversy on the necessity for efficient methods, motion economy, time standards and planned materials handling. Wherever the repetitive nature of the product allows, we should make the fullest possible use of *all* these scientific aids to productivity. When conditions are such as to permit flow production technique, such aids should be applied with vigour and foresight. Where flow production is not possible, the least costly and most effective means of raising productivity is, without question, planned materials handling.

Unfortunately, as most supervisors and foremen know, British industrial capacity is in the aggregate made up of smaller production units employing less than fifty workers. In many of these units, the nature of the production is *non-repetitive*, i.e., whilst conforming broadly to type and character, such manufactured products are in part "tailored" to suit special requirements. Owing to the individual features considered by customers to be necessary, it is impossible to obtain more than a limited measure of standardization. This in turn restricts quantities to very small lots.

Under such conditions, it is manifestly absurd to attempt centralized planning together with time and motion study. In the absence of the prime factor—*quantity*—both techniques merely increase indirect expense resulting in an unnecessarily costly product.

Sense of proportion

Scientific aids to productivity can be effectively employed only when conditions suitable to their application can be instituted. There must be proper regard to the economic principles upon which all industrial activity is based. This applies very much to time study, often used when good ratefixing would prove more suitable to the type of production technique, and the nature of the product.

Generally speaking, there is a far wider field for the application of ratefixing than of time and motion study in Britain. That must inevitably hold good until the traditional emphasis on the production of *capital goods* and *equipment* gives way to the American idea of consumer goods, such as cars for *all*. It must be remembered that American manufacturers have for long concentrated on the home market as a basis for the quantity production of low cost products. Britain, on the contrary, has mainly directed her industrial activity in the direction of capital goods, which are not sufficiently *repetitive* to permit full exploitation of intensive tooling methods, or, time and motion study; either of which require *standardized* conditions before the maximum economies can result from their use.

The foregoing does not in any way detract from the rational and beneficial application of time control, improved methods or motion economy in *most* industries including those employing a small number of workers. The objective, however, must lie in the direction of improved methods, the widespread adoption of simplified handling, a reduction of the fatigue factor, with the ultimate aim of so raising productivity that *basic wages* will increase proportionately to the rate of output throughout industry.

It will be appreciated that this is quite opposed to the accepted idea of maximum individual *earnings*, but in any event, only an aggregate increase of productivity throughout an industry could lower costs, increase basic wages, raise purchasing power and stimulate consumer demand.

Ratefixing

Most ratefixers graduate from the ranks of machine, bench hands or process operatives and are usually men of high practical skill. In spite of these qualities, however, they lack in many instances adequate knowledge of ratefixing technique; perhaps because there are no schools for the teaching of practical ratefixing superimposed on an adequate educational background.

To illustrate the deficiency to be observed in the training of ratefixing personnel, it is proposed to quote J. J. Gillespie, a well-known consulting engineer, whose findings are based on an investigation he carried out and related in his book, *Engineering Reorganization:*—

> *"Examples of inadequate technical knowledge resulting from questions put to twenty-eight ratefixers and eight process engineers in nine different works:*
>
> 1. Not one could produce tabulated data in daily use to cover cutting tools.
> 2. Only two possessed data relating to metal tensile strength and/or Brinell.
> 3. All put much the same fatigue allowance on the job whether the operation called for manual effort for 100 per cent or twenty-five per cent of the operation time.
> 4. Only seven were able to handle effectively the setting of rates on machines, two or more of which were worked by one operator.
> 5. In only two of the nine works were machine capacity charts in use.
> 6. Only one of the nine works used constants, and in this case these constants were few and of little real use."

This investigation reveals a lamentable state of affairs and may well be a pointer to the low standard of industrial relations in some works, where ratefixing lacks the confidence of machine and bench operatives, so causing an effective brake on productivity, rather than a means of promoting confidence, stimulating effort and lowering costs.

Between ratefixing of the lowest order and the opposite extreme of highly specialized time and motion study lies the middle path of synthetic ratefixing by the comparative method. Scorned by the ardent time and motion study advocate, it has proved nevertheless to be adequate for the greater part of British industry, where highly repetitive production techniques cannot be applied. Before passing on to synthetic ratefixing, it would be well to take just a broad glance at time study *in extenso*.

Time study

In many small engineering and other shops one frequently hears derision heaped upon the practical works-trained ratefixer, but it is nothing compared to the wholesale contempt reserved for the time study fanatic who—although a specialist on the Bedaux system—finds himself all at sea in a small factory, where the largest batch may be something less than fifty. Such an expert is likely to discover very speedily that he knows as much about shop practice as a mermaid about atomic fission.

On large-scale assembly such as radio, vacuum cleaners, packaging operations, chocolate enrobing and similar flow processes, where continuity permits a high degree of mechanization, there is a legitimate field for the employment of time study in all its glory. In the majority of British factories—and the majority employ less than fifty workers—the time study man is a costly ornament, and his stop-watch about as useful as the home town clock to a traveller in the Sahara desert. Time study is an asset in the highly repetitive concern where materials, methods and machines are so organized as to produce "standardized conditions." Even so, there is still the "x" quantity, the *man* who so far has proved intractable to all the efforts made to standardize *him*.

Time study, in fact, claims to be so highly scientific that the field it embraces trespasses more than a little into the realm of medicine. If this appears to be an overstatement, then read *Applied Time and Motion Study*, by Walter G. Holmes (publishers: Ronald Press Co., 1938). This masterpiece of pseudo-scientific literature provides tables of neuro-biological reactions which, in simple language, means the time taken for impulses to travel from the brain to the various muscle groups via the motor nerves.

In another well-known text-book, *Motion and Time Study*, by E. M. Barnes, one may find tables of oxygen consumption for various tasks involving the expenditure of physical energy. These tables naïvely conclude that a labourer consumes less oxygen in pushing a wheelbarrow at a normal brisk pace than during a slow walk or gentle run.

Let us take a glance at the brain reaction figures of Walter G. Holmes:—

TIME IN DECIMAL MINUTES

Nerve Reaction

Eye to Brain or Reverse		0.0003
Hand to Brain	,,	0.0024
Knee to Brain	,,	0.0026
Foot to Brain		0.0030

* From a paper presented at the Mechanical Handling Exhibition and Convention, Olympia, June, 1950.

Realize Contact	0.0010 to 0.0040
Hear or Smell	0.0025 to 0.0040
Mind Decision	
Mental Process	0.0010 to 0.0100
Finger-Hinge Movement	
From Knuckle: 0 to 2in × 5°	0.0017
0 to 4in × 10°	0.0021

Are we really to believe that time study experts are in possession of data on neuro-biological reactions which a handful of eminent medical specialists, scattered all over the world, have taken many years to obtain by painstaking research? Surely this is hardly conceivable!

Is Britain's ability to achieve economic stability dependent on her workers attaining a standard time of seventeen-thousandths of a minute to move a finger from the knuckle for two inches through five degrees, or, would we do better to rely on adequately training our workers, efficient management, good foremanship, alert supervision, not overlooking that quality of cratfsmanship which once made British Industry famous throughout the world?

What possible scientific or biological justification exists for the alleged standard measurement of human reactions? Practically every book on time study first oversteps the reasonable bounds of scientific veracity and thereafter becomes extremely unscientific by talking about "approximately" or "nearly." In precision engineering, a ten-thousandth part of an inch is accurate work which often causes many heartbreaks; yet, time study virtually blinds science by glibly claiming an accuracy of one ten-thousandth part of a minute for human brain reactions.

Most people would agree that in any industrial concern a fairly representative cross-section of men and women are to be found in all their diverse types. No two men are alike, each reacts strictly in character with type and temperament to a given set of circumstances. Those who write so lucidly about neuro-biological reactions should carry the pseudo-scientific jargon to its logical conclusion; they should explain precisely how the four basic human temperaments vary in their response, and what effect the state of the glandular system has on the so-called *standard nerve reaction times*.

It may be appropriate to suggest that some time study exponent with the necessary qualification will amplify these fourth decimal minute reactions, subdivided as between the four basic human temperaments—the *nervous*, the *choleric*, the *melancholic* and the *phlegmatic*. Each individual is conditioned by the endocrine glandular system, and each reacts according to type, to internal or external stimuli or conflicts.

Notwithstanding anything in the foregoing, there is undoubtedly a legitimate field for the application of rational time study, the operative word being *rational*.

Where process cycles or machine operations are principally *mechanical;* where conveyors, infra-red paint drying tunnels, pottery kilns or automatically controlled handling equipment are involved, there is definitely no legitimate field for time study. Improvements in process work of this nature can be reasonably expected to emanate from improved methods and to whom, if not the production engineer, should one look for dynamic product engineering? If the time study expert feels himself capable of improving manufacturing methods, surely he should become a production engineer—Britain needs such men badly enough. Since the time study expert claims that *standard* conditions are essential for standard times, certainly his first duty is to help establish those conditions as a basis. It cannot sufficiently be stressed that Britain's industry must urgently exploit standardization to the fullest possible extent.

The proper field for time study is in the reduction of non-mechanical cycles, i.e., in work of a manual nature, mainly of an unskilled character, or, where operators are specialists in a very narrow field —women on light assembly, in the clothing trade, provision and cereal packaging, in most of the luxury trades like cosmetic manufacture, pharmaceutical packaging and preparation. Within those fields where manual dexterity plays an important part and constitutes the larger portion of the production cycle, time standards are essential to the maintenance of standard costs. Where machine operations are concerned, there is little the time study man can do, provided the production engineer has processed the product with that efficiency one should be able to expect. If materials, machine speeds, feeds and tools have adequately been considered, any given equipment should be producing at optimum rate. Predetermined standards laid down by a production department can be very accurately computed by synthetics based on constants collected within the works where they are applied. On condition that such standards are supplemented by a plus tolerance figure (within the standard cost), there is little improvement to be anticipated from the use of the stop-watch. Were any such improvement demonstrated, it would be high time for a concern to find another production engineer or, alternatively, to offer remuneration commensurate with the degree of skill and training required by dispensing with the stop-watch department expense.

Britain needs dynamic production men with a good background of ordered practical apprenticeship plus adequate qualification obtained by means of a sound training in technology, economics and administration. Only when such a body of trained men are available and in a position to achieve a renaissance of British production technique, will it be appropriate to bring the stop-watch into action, where it is proved that efficient technology has failed to bring results.

Time study to the nth power

If after very careful analysis it is found that the average size of British industrial concerns, in relation to the type of production, is suitable for all-out time study, let us by all means extend its use. In so doing, however, we must be prepared to justify its introduction by carrying it to its logical conclusion—apply time study from top to bottom of any concern where it seems evident that increased production at *lower cost* will result inevitably from its introduction.

Prior to the installation of time study, it is of paramount importance that:—

(1) The type of product and its repetitive nature shall permit the use of standard methods, materials and even machines.

(2) A high degree of standardization has been achieved so as to establish the degree of stability essential to the "standard task" as a reliable measurement of production efficiency.

(3) The sales volume of a product over a reasonable accounting period can be forecast with reasonable accuracy.

(4) The volume is sufficient to justify standardized methods, efficient tooling and job breakdown into elements.

The conditions outlined are the minimum for a manufacturing industry, but in packaging and confectionery production, etc., the field for the application of time study is much wider and the basic requirements less stringent.

Time study, even when applied to high-class product engineering, will not alone result in such savings as might be anticipated. Unless extended throughout an organization, it is illogical to cut minutes off an operation time-cycle, whilst hundreds and perhaps thousands of hours are wasted on the indirect expense side. An analysis of such wasted hours spent in conferences, progress meetings, excessive paperwork preparation, and the vicious circles of high-pressure indecision often encountered, accounts to a great extent for the high selling price of many products.

Direct procedure, simplified routine and clear-cut designation of responsibilities would lead to less top-heavy administration from which both British industry as well as government are suffering. If time study can truly make a worthwhile contribution to our economic salvation, then let us analyse the job of *everybody* concerned on the administrative side of an enterprise. How does the average executive spend his day? How many progress meetings does he arrange to ensure that subordinates—delegated and paid for a job—will not fail to discharge their responsibilities? Let us be sure that the irreducible number of executives and administrators are employed; that functions and duties are clearly defined; that such responsibilities as fall into the specialized class are delegated to *qualified* and *efficient* subordinates, who can be trusted to bring to light only such matters as may run contrary to a predetermined plan.

In short, let us be satisfied that every employee not engaged on productive work is assigned a clearly defined but *essential task* and that it is performed with the same standard of efficiency which time study aims to achieve in productive tasks. There cannot be two kinds of logic, nor can there be one measurement of efficiency for the manufacturing and another for the administrative side. If a *standard performance* is essential for manufacturing operations, it should be no higher than the corresponding standard for administration.

Many will retort that administration is *different*. What *is* the difference between an assembly operation comprising delicate manual handling and the man or woman preparing a material schedule? If the former can be measured in terms of a *standard task*, surely, there is no unsurmountable problem in measuring the latter in like terms?

Looking dispassionately at time study, we find that it views all industries alike. It is not uncommon to meet with the same group of "experts" engaged at different times in introducing time study in cotton mills, garment factories, engineering works and other widely divergent productive units. This may be an argument for the pure *scientific basis* of time study, but if so, there must be inevitably many gaps in the practical application of the theory.

Incentives

Incentives must be provided if productivity is to be increased and costs vigorously pruned. There is, however, one aspect relative to incentives which is nowadays either glossed over or completely ignored, i.e., the failure to provide incentives for those technicians who are responsible for evolving the basic con-

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ditions without which it is quite impossible to provide incentives for operators, much less to establish the fundamental conditions essential to greater productivity.

Think for a moment on the average engineering works where batch production is in being. The alpha and omega of the productivity potential depend almost completely on the ability of the planning engineer, who lays out the sequence of operations, decides the methods for good or ill and evolves in many instances the tooling, with proper regard to the economics of quantity.

Balance the incentives of such a man against those of the skilled and semi-skilled operator. In the first case, the average wage is about 25 per cent higher than pre-1939, and there are no bonus earnings on output. In the second case, there has been wage increases averaging 70 per cent, plus bonus earnings amounting often to 40 to 60 per cent of the basic wage. It is not unusual that the operative, for whom the work is planned and organized, averages higher earnings than the man who made such earnings possible, namely the planning engineer.

If this island needs greater productivity for survival, it must introduce more efficient methods, improved handling and incentives for the "back room boys." There is a long way to go before Britain has built up an adequate supply of properly trained production technicians. To do this, it is essential to keep in the forefront the elementary principle that, in this important field of work, incentives cannot be ignored. On the quality of her production technicians depends Britain's ability to hold even a subordinate position in international trade. Without production technique, there would be no work for operators; no field for cost accountants; no scope for management and no source of investment for capital either State or private.

Production technicians of the right calibre are difficult to come by these days. The reason is not obscure: there is no incentive to attain the necessary standard of education and experience, because the return for effort is often lower than that of the productive worker.

With all the talk of increased productivity, it is astonishing that so elementary a fact has escaped the notice of politicians, employers and even the Chancellor. Incentives, to be equitable, must be distributed proportionately to all who contribute to raising output, but special training and technical education must be justly recognized.

If time study could offer a solution to the problem of incentive for *essential* indirect personnel, it would render a service to the entire British nation; the operative word is *essential*.

A number of skilled craftsmen were recently asked, whether they would not like to become probationary planning engineers. The first question they put was relative to wages; when told the amount, they one and all declined on the ground that they could earn more in their present job.

How can we expect to attract the best *practical* men who would be prepared to undergo further training in technology as potential production engineers, unless we offer reasonable incentive to compensate for loss of bonus earnings? That this is a mistaken policy is quite clear, but where did such a policy originate, and who could possibly be responsible for such muddled thinking? Incentives by all means, but to deprive industry of the right type of engineer by offering them less than they could earn on the machine or at the bench, is surely the height of folly.

None but the properly trained technician is capable of providing the conditions essential to the delicate balance of the three basic factors, *method, motion* and *time,* and linking them closely to the handmaiden of mechanization—*materials handling*.

In the absence of the fullest comprehension of the urgency of those factors, our industrial technique will fail to blossom and the tree of economic progress become sterile. It would be an inspiration to model a syllabus on a new concept of training designed to turn out technicians of a class comparable in status to that of the American production engineer. That would be at least in keeping with the march of time. Such men would, of course, have to be educated to appreciate the difference in the relative *quantity* potential as found in the respective countries according to their area. This is an urgent problem, since it is not any longer possible to escape the fight for a place in world markets.

Motion economy

Motion economy, although generally thought of as an integral part of time study, is in reality quite separate and distinct. A little consideration will show that motion economy has much more in common with *materials handling* than with time study.

As the name implies, motion economy is directly concerned with the problem of human effort: the elimination or reduction of fatigue. Naturally, it cannot be denied that the primary objective of motion economy, is increased productivity. Unlike time study, however, motion economy is directed to *true labour economy* and the elimination or reduction of fatigue is a possibility in practically every industry repetitive or otherwise. Hence, there is a very wide scope for the exhibition of motion economy which first analyses and then co-ordinates two of the basic factors mentioned previously, i.e., *motion* and *method*.

It may be said that motion economy, whilst broadly pursuing the same end as time study, nevertheless seeks to achieve its purpose in a rather subtle, but interesting and certainly more humane way. Humane, that is, if anything associated with the machine age, in the light of current economic policy, can be called humane.

The principles of motion economy can be stated under three divisions:—

(1) Reduction of fatigue in the usage of the human body.

(2) Location and layout of the work station.

(3) Design of tools, fixtures and work-handling equipment.

From these three classifications it will be quite clear why there is so intimate a link between *motion economy* and *materials handling*.

The two factors *method* and *motion* are of fundamental importance to motion economy or, as it is sometimes called, motion study. Indirectly, those two factors are closely related to the third, i.e., *time*. It will be obvious that method largely governs motion and that time is the resultant which, together with the sum of the variables, determines the labour cost of a given product.

Time, once expended, is beyond recall. It can, consequently, be concluded that any time expended in excess of what ought to be taken in performing an operation, handling or transporting material, must increase the cost of the product as inevitably as the taximeter ticks up the cost of waiting time.

Motion, by which we mean the movement of hand, feet or body associated with the performance of a manual task. In a broader sense, motion can also be related to the movement of materials, semi-finished and finished products during the various stages of processing, whether governed by manual or mechanical aids or a combination of both. In the widest possible interpretation, motion can be visualized as the means by which goods and materials are transported long distances *en route* to the consumer. All motion is relative in terms of time and hence in cost.

When considered in relation to a manual operation, a motion may be defined as a compound series of actions made up of a number of units of motion. A motion unit represents the smallest action which is measurable in terms of time—whether impulses from the brain, which cannot be seen, are to be included in this definition is a moot point; their exclusion will not materially affect the national economy.

Method is the term used to describe the *plan of activity* associated with the performance of a given task. It is the simplest, least laborious, most logical and generally the least expensive way of carrying out a process. The sequence of successive operations which go to make up a process are planned in an order designed to give the most economical result. The facilities, i.e., the tools and equipment, the feeding and disposal of material and the layout of the work station, combine to make the plan or method.

At this point it is appropriate to stress the role which ought to be played by foremen and supervisors. Their experience can find expression in devising the best method of performing a particular operation. Technical personnel should at all times draw on the experience of foremen and supervisors before finalizing a plan of activity. There is a fertile field for the development of good team-work where method is concerned. Supervision is, or should be, in intimate contact with operatives and it must not be concluded that the man who performs the operations is completely devoid of ideas on method.

Motion economy, then, will to a great extent depend on method, and for that reason can be applied to many tasks of a non-repetitive nature.

Very largely due to motion economy, it has been found possible to train blind and partially sighted persons for light assembly; in certain circumstances, even for machine operations where special safety precautions have proved practicable. A great deal has been achieved in training blind or disabled people to perform useful work by the patient and human application of the principles of motion economy. In this connection, the layout of the work station, the predetermined location of tools and fixtures, and the fullest possible use of planned method, has contributed much to the success of the blind and disabled in performing operations normally done by sighted and able operatives.

Motion economy rests on the basis of eliminating movement, reducing the extent of movement and in ascertaining the combination of movements which will give the most economical and least tiring sequence. The position of the operator, work bench, machine, component trays, bins, conveyors and the relative dimen-

sional layout will ultimately determine the expenditure of energy and the cost of performing a given operation. The sequence of using materials and tools should be so arranged that the cycle of movements passes from one side to the centre of a working area, conforming as closely as possible to an arc or semi-circle.

The principles can be applied with equal facility to bricklaying or bootmaking, hairdressing or ham curing, and the more manual labour involved the wider is the scope for motion analysis. It should also be said that the greater the need for reduction of fatigue, where heavy labour is concerned, the greater is the need for mechanical handling.

There are certain principles governing motion economy most of which are equally applicable to materials handling:

Work Stations

(1) Fixed stations for all tools and materials should be provided.

(2) Controls, tools, components and materials should be situated as closely as possible to the front of the operative.

(3) Gravity feed trays, bins or containers should be utilized to deliver material or components as closely as possible to the assembly or usage point.

(4) "Drop deliveries" or magazine feeds should be employed on every practicable occasion.

(5) Tools, components and materials should be located to permit the use of the best, least tiring and most economic sequence of movements.

(6) The height of tables, machines, equipment and appliances should be arranged with a view to the easiest accessibility and least fatigue.

Tools and Equipment

(1) The hands should perform only such work as cannot be more advantageously performed by the feet or other parts of the body.

(2) Wherever practictable, two or more tools should be combined as a dual purpose appliance.

(3) Tools, materials and equipment should be as far as possible in predetermined locations.

(4) Control levers and hand wheels should be located in positions that permit easy manipulation by the operator. The objective is to operate such controls with the minimum change in body position and the maximum mechanical advantage.

Compare the foregoing principles with the questions the production engineer must ask himself as a preliminary to planning a materials handling installation:—

(1) Can the number of times the material is handled be reduced with properly designed equipment or appliances?
(2) Is it possible to reduce the distance the material must be moved?
(3) Are suitable bins, containers or trays used for receiving, storing and moving the materials?
(4) What delays are experienced in the delivery of material to the operator or processing point?
(5) Can the operator be relieved of manual materials handling by the use of conveyors or other equipment?
(6) Is the existing equipment the most suitable and economical for the work?
(7) Are ample facilities provided for the maintenance of all equipment in a condition of safety and efficiency?

The close relationship between motion economy and material handling can now be seen clearly, this being ample justification for stressing the complementary character of the two as a means of raising productivity.

The importance of *motion* and *method* will become all the more evident when expressed in a single sentence, such as the following:

Time involved in the unnecessary transport, protracted handling or prolonged storage of raw material, semi-finished or finished products is often the main single source of loss in industry.

A parallel statement could be made regarding plant and equipment:

Idle manufacturing plant, machinery and handling equipment represent time in which a part of the invested capital lies idle.

Loss from either of the above causes is reflected in lower total turnover, i.e., in the numerator of the ratio

$$\frac{\text{Indirect Cost}}{\text{Direct Cost}} = \frac{\text{Numerator}}{\text{Denominator}}$$

Direct costs relative to any department will always be directly proportional to production volume, but the numerator is unlikely to conform to any such precise mathematical ratio. As will be appreciated, the least controllable factor in the ratio is the numerator, and the sources of serious leakage are to be found in the items under materials and plant. These factors could be reduced to a minimum by foremen and supervisors willing to develop "cost consciousness."

Far bigger dividends are likely to accrue from a considered application of the principles of motion economy and materials handling technique than ever could result from the extended use of time study.

Ratefixing techniques amplified

It is customary for exponents of scientific management to laugh at the comparative method of setting a rate. Is there anything very funny in comparing a particular job with a similar one already being rated? Bearing in mind that the major part of British industry is not highly repetitive, it is a fair question to ask: "What is the sanest and least expensive method of rating from one to ten similar parts?"

Comparative ratesetting certainly has many weaknesses, the principal being the possibility of multiplying previous rating errors. This important weakness can be eliminated by breaking down operations on standard sheets and taking each element separately for comparison. All such standard sheets should, of course, be retained for future reference. Operation breakdowns need not be in infinite detail but just sufficient to reveal the *similarities* and *differences* between the two jobs under comparison.

The calculation method of ratesetting is extensively employed on sheet-metal cutting, forging and welding. When used in relation to machine shop work, it is customary to calculate times on the basis of speeds, feeds and depths of cut. Setting and handling times are by this method generally based on recorded experience.

Properly carried out, where capacity charts for the machines are available, the method is more economical, reasonably accurate and certainly more sensible for very small lots than time or work study.

For larger batch work of from twenty upwards, the synthetic method of rate setting has much to recommend it. The advantage of this method is that it can be used in combination with other methods.

Generally speaking, the synthetic method is based on constants collected by time or work study. In any case, all job rates are carefully analysed for recurring constants, which are extracted and filed under an appropriate heading.

Constants for preparation time, grinding, mounting and setting tools are easy to collect, as also are constants for general fitting, sheet-metal, welding, forging and painting work.

The fatal blunder of attempting to make use of constants collected by other people under different conditions is frequently made, and this kind of mistake can lead to serious troubles between ratefixers and operators. It is not uncommon to find synthetics and constants collected under repetitive conditions, and large batch production, being applied in shops where batches of over fifty are the exception.

It should be self-evident, that to set rates on very small batches on the basis of "X" hours per thousand is likely to bring ridicule and distrust upon the head of the ratefixer or ratesetting department. Furthermore, it will be abundantly clear to anyone with the slightest knowledge of ratefixing that, when such figures as "X" hours per thousand are specified, it is an incontrovertible fact that the synthetics and constants were collected in some place other than that in which they are applied.

When synthetics and constants recorded under large batch conditions are utilized for very small quantities, the rates set will generally be too low. This will result invariably in adjustments having to be made either during or after the completion of the job. When adjustments have to be made in more than 30 per cent of all jobs issued to a shop, it is safe to assume that:

(*a*) the ratesetting is based on synthetics collected under conditions varying from those under which they are applied;
(*b*) the ratesetting department is incapable of handling the class of production; or
(*c*) lacks the qualified staff to collect and collate the essential data from the actual shop in which such data are to be used.

It must be remembered that large batch production is normally carried out under more stable and standardized conditions than is possible or economically advisable with short run production. So big is the variation in the synthetics of the two types of production that, in spite of adjustments before actual issue of a rate, there is an inevitable margin of error on the minus side. From a plant loading standpoint, these errors are on occasion likely to prove disturbing. If delivery promises are made on the basis of ratefixed times, which eventually prove to be from 30 to 50 per cent low, any attempt at plant loading is rendered abortive.

In factories where batches of from five to fifty are customary, synthetic ratesetting can be very effective and is the least costly. This method is well worth the initial expense of collecting the data in the shop in which they are to be applied. If that is done efficiently, there will be a sound basis for plant loading and progress. Reasonably exact ratesetting is a prerequisite of effective production and cost control, as well as a means of accurate estimating for the purpose of tendering.

Summary

As a result of the various points made in this Paper, many of which are controversial and provocative, it is hoped that the interest of foremen and supervisors will be so aroused that they will develop their own line of thought on the

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many problems and seek, find and apply their remedies. The solutions may vary in nature, but provided they do not materially depart from basic principles, more good than harm will result from different ideas. Teamwork also counts considerably, and what better teamwork could there be than a gathering of foremen and supervisors, stating, discussing and solving their manifold problems?

There is one further aspect of job rating which needs to be made clear, whether the method of rating is by means of time study or ratefixing, i.e., the *lack of uniformity* in different factories, even in those where similar products are manufactured.

Time study or ratefixing is intended to be a standard of measurement for the purpose of accurate costing and as a means of assessing efficiency. Unfortunately, neither time study nor ratefixing can be said to be adequately fulfilling their proper function.

Under existing conditions, there can be little hope of a uniform standard for a given operation or process as between various firms, because each evolves an individual system of allowances over the normal time for a given operation. There are such wide differences, therefore, in the standard times for similar operations, that comparisons of efficiency becomes virtually impossible.

Many firms do not use their job or operation rates as an efficiency measuring standard, but rather as a method of offering an acceptable wage level. To attain any standard of comparative efficiency, it would be imperative to standardize basic wage rates for similar work and abolish the practice of weighting time standards to suit wage policy.

As an example of this kind of policy: many firms recognize normal bonus earnings to be of the order of from 60 to 80 per cent, and operators in such firms often demand and obtain double time before they will even pick up a job. Such policy usually implies that wage rates are kept at the lowest possible level and that merit awards for ability are entirely lacking.

On the other hand, the existing principle has been clearly defined, i.e., that an average performance by an operator should permit 27½ per cent to be earned with the rating issued for the job. Under proper conditions, a good operator might be able to earn 40 per cent; if returns should be higher, either the operator is exceptional or the method of rating unsatisfactory. How many firms in practice are in a position to operate under conditions of a minimum of 27½ per cent for average performance?

Based on the text of this paper, the following conclusions emerge:—

(1) Time study can do little to increase productivity, except in highly repetitive or in the light industries, where females are employed, mainly on manual operations of an unskilled highly specialized nature.

(2) Time study is not complementary to materials handling; the latter could alone appreciably increase production in most industries.

(3) Motion economy and materials handling *are* complementary, and applied together could contribute to a marked increase of output. Irrespective of whether an industry is non-repetitive, large or small, there is a field for doing things easier and more economically. Motion economy can lighten the fatigue of repetitive or non-repetitive work. Materials handling can lift, shift and transport liquids, solids and gases to any place required in a controlled time cycle. Some manual transferring is often necessary, but motion economy since it studies method will focus attention on the easiest way.

(4) Synthetic ratefixing based on speeds, feeds, depth of material removal, together with constants and data collected in the particular factory, provides all that is necessary in the majority of British works. This must be so since the majority of factories in this country employ less than fifty workers; are neither highly repetitive nor in a position to offer the *standard conditions* which are essential to time study technique.

(5) Time study, in any case, is not generally applied as a standard of measurement, but rather as a method of bolstering up a low wage-earning level. *Standard times* are often increased by allowances under various guises, in order to supplement the basic hourly wage. Such allowances are generally called an incentive scheme, but it would be less expensive to adopt a simpler method of arriving at a reasonable incentive.

As a suitable ending of this paper, it might be appropriate to pose a question: "Why bother at all about time?"

Some fifteen years ago, a story (later found to be authentic) was told of an industrialist who decided that time study and various scientific management theories had failed to give him the results he expected. Consequently, he started to blame himself for bad management and accordingly went to the other extreme by abolishing time study, time control and time clocks.

First of all, he divided his factory load into shop programmes with a target output for every machine and working group. He established a target delivery date for every job in the factory.

Next, after having removed time clocks, he informed the employees that in future he would regard every department as a team and pay them the highest wage rate in the area for their particular job. In addition, he would give them a bonus for every hour saved against the target date. All men were told that he did not mind who took the afternoon off to go to the sports ground, that was up to the departmental team. They could do as they pleased provided the targets were met, and if they did not wish to earn the bonus for beating the target, well, that was their affair. No stoppages were to be made for time-off nor any disciplinary action taken unless requested by the committee in the department concerned. Do you think this seemingly crazy experiment resulted in chaos and bankruptcy? Far from it; output increased to a peak previously never reached. Production costs took a downward curve and all target schedules were handsomely beaten.

How was it done? For the first week or two, there was a fair measure of time-off due to the newly founded policy of freedom. It did not last very long before the shop committee exercised their own disciplinary measure. The lazy were soon either reformed or dismissed, at the request of their colleagues, who considered they were being victimized by the slackers.

This may not be an experiment to be recommended for universal adoption. It is clear, however, that the industrialist who made this revolutionary change must have possessed a remarkable insight into the complex character of mankind.

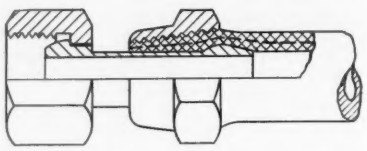
Perhaps, in this mechanical age, it might well be that a study of man, his longings, needs and aspirations, would pay richer dividends than an intensive research for new methods of prodding him on; or more original means of suspending the carrot before him.

These questions will all, doubtless, be solved in the passage of time. Meantime, the problem of producing enough to sell at a price our overseas customers are willing to pay is still with us and it must be solved if the nation is to be fed, housed and clothed.

Low Pressure Hose

A RANGE of hose assemblies used in the commercial vehicle and motor industries is offered by Aviation Corporates, Ltd., 50, Pall Mall, London, S.W.1. The hose is made in a range of three different qualities of synthetic rubber, depending upon the pressure required, and is suitable for all normal industrial fluids and pneumatic services. An abrasion resistant synthetic rubber outer cover is provided in place of the customary wire overbraiding.

Two types of end fittings are available, that normally supplied having a short, crimped ferrule. Alternatively a new type of re-usable coupling can be supplied, as shown in the accompanying illustration. It will be seen



Re usable hose coupling.

that the insert has an enlarged diameter over which the hose can be forced. The taper nut is then tightened on to the outside diameter of the hose and the assembly is complete.

It will be evident that this type of coupling is suitable not only in situations where it may be necessary to renew a hose connection in emergency, but also for test and experimental departments where assemblies can be made up quickly on the spot to suit individual applications. The hose is available in four sizes ranging in inside diameter from $\frac{3}{16}$in to ½in to suit working pressures varying from 335 lb per sq in down to 165 lb per sq in, according to diameter. (1907)

DUNLOP SPECIAL PRODUCTS LTD., Fort Dunlop, Erdington, Birmingham, 24, have recently issued a new manual dealing with Adhesives and Composition, many of which are applicable to the motor industry. Details of the various adhesives are given in the form of data sheets in which their characteristics, typical applications and method of supply are specified. In some cases the technique of application is also covered.

Institution of Mechanical Engineers, Automobile Division

AUTOMOBILE TEST RIGS

A Description of Typical Equipment, Indicating its Scope and Results

By L. H. Dawtrey, M.I.Mech.E.*

The paper opens by describing the background of automobile rig testing, with the word "rig" defined as "a contrivance or makeshift with the means at one's disposal."

A range of equipment is desirable so that rigs can, after use on one particular test, be reassembled to form some other device, after the fashion of a constructional toy.

It is made clear that no indoor test can replace the testing of vehicles on the road, or tractors on the farm, but useful and quickly obtained results can be acquired with certain problems. Such work can be useful supplementary aid to a development programme.

As the essence of the subject is variety and speed, it is felt necessary to give several illustrations to emphasize the simplicity and ingenuity required in rig construction and design. The use of photographs in lieu of engineering drawings as an aid to later reconstruction is mentioned. Test rigs illustrated include those for fatigue failure in suspension, frame, body, and transmission: impact failures; body and chassis weaving; tractor and car transmissions; valve port flow; roller bearing wear; and vehicle air resistance measurements. Enough technical data is given to show the scope and results of the tests.

TEST rigs are not a new development in the automobile industry, nor are they confined to this industry. The practice of using these methods of testing in the work of the experimental shop has, however, grown increasingly, particularly during the past fifteen years. The author will deal with a few typical rigs chosen from the large number which he has used during the past decade. The main theme of the paper is the unlimited variety of form and purpose which is to be found in such test rigs.

The term "rig" has become commonly accepted as the designation of machines of this type, and on referring to *Wild's English Dictionary* it is confirmed as an eminently suitable term, although the word has other meanings. In one instance we find it stated that "to rig" is to manipulate dishonestly. Now, it must be admitted that the rig builder has been known to raid the plant engineer's stores, in order to acquire odds and ends of equipment, but in an entirely legitimate manner. We may, therefore, ignore this definition.

In a further instance we find the real meaning of the subject of this paper stated in the perfect description: "To erect, construct, contrive, especially as makeshift, with means at one's disposal." This explains the difference between a rig and a permanent testing machine.

Environment

Let us consider the background against which the test rigs, to be described, operate.

In the author's youth the experimental shop in an automobile works was a small place, with a single test bench for engine development, room for one or two cars with a pit for working beneath the vehicles, and two or three work-benches. Very good work was done in those small back rooms, a fact which is not surprising, as it is the quality of the men far more than the equipment which is of first importance. Nevertheless, good men allied to ample equipment will surely produce better results.

The modern automobile experimental shop is indeed a substantial place. It may provide space under one roof for some twenty or thirty vehicles, some of which are for road testing and attached permanently to this department. Other vehicles will be there for a short period with reference to some particular problem or nspection. For the maintenance of these vehicles are provided numerous work benches, car washes, lifting ramps, a paint booth, and an area devoted to lubrication and similar requirements.

There is accommodation for building prototype chassis units and complete vehicles, involving a small machine shop, complete with jig borer, a tinsmith's section, and welding plant, together with numerous compressed air and electrical pick-up points so common in modern workshop practice. The body experimental and prototype rooms are to be found within these walls, while a substantial pattern-making department is also included.

Some idea of the area nowadays devoted to this important section of the engineering department may be gained from the dimensions of the experimental shop possessed by the author's firm. It has a length of 352 feet and a breadth of 125 feet. All storage space is provided by outbuildings accessible from within the shop, making the overall breadth 147 feet.

In this particular experimental shop it has long been the practice to arrange space for a fully equipped physical testing laboratory, designed not only for normal material testing, but to be always available for experimental work. It is in the physical laboratory that rig testing has grown, blossomed, and borne good fruit. In addition to a 30-ton hydraulic tensile testing machine, there is still retained an old, steel-yard type, 25-ton mechanically operated tensile machine, which is adapted, as required, to rig tests. As this machine was additionally made for torsional testing, this feature has been further developed. For instance, the torque arm has been doubled in length, in full reliance on the high factors of safety used in the original machine designs, and a fixture arranged at the beam pillar location, as an alternative position for the torque-applying worm and wheel. This allows units of substantial size to be subjected to torsional forces, by utilizing the space between the pillar and the machine body, as shown in Fig. 1.

Another useful machine for rig testing is an old steel-yard type, 3-ton, laminated-spring-testing machine, which, apart from its normal use, is available for any rig test requiring measurements of load. Here again overloading has been practised on occasions, by loads up to 5 tons, and on more than one occasion this machine has been used as a screw clamp to hold a chassis frame undergoing vibratory tests.

The physical laboratory has the usual complement of material hardness testing machines, together with a range of dial-type, coil-spring test machines, covering load capacities of 20–2,000 lb. The provision of sufficient means for driving the rigs is of great importance for rig testing, thus this laboratory contains a wide range of electric motors, usually with variable speed control, some being permanently mounted and others mobile.

Within this modern shop are sound-proofed air-conditioned engine test booths containing five permanent test-beds, with accommodation, when required, for rigging two or three additional test stands, which may be dismantled and replaced by rigs for entirely different purposes.

Fig. 2 shows one such booth with a permanent electrical test-bed in one half, while in the floor of the other half will be seen tee-slots in the form of a cross. These hold various rigs, such as the two engine test-beds shown. Water-brakes are, in this case, installed, but not in the field of view of the illustration.

There is also a "silent" test-room designed to hold a vehicle either for chassis dynamometer tests or for rear axle development, and also two dark rooms for stroboscopic work.

When an engine is mounted on a specially designed engine test-bed this would not be referred to as a test rig, but if a complete tractor was mounted on such a bed it would fall within the scope of "a contrivance with means at one's disposal" and thus be a rig. Similarly, if an axle test house is made to accommodate a vehicle it may be to some extent a rig. Some rigs may be placed in a large refrigerator if low-temperature tests are required.

Even with the exceptionally large amount of test rigs operated, the man hours devoted to rig testing will not exceed 10 per cent of the purely mechanical engineering work, or perhaps 5 per cent of the complete range of experimental work.

Not all rigs are successful in giving the results desired, as shown later in this paper. Rigs may be devised to test for endurance against wear, material fracture, or structural stiffness.

Typical test rigs

Rig Tests Designed to Produce Fatigue Failure. Over the years it has become recognized that material failure occurs

* Technical Engineer, Standard Motor Co., Ltd., Chairman of Coventry A.D. Centre.

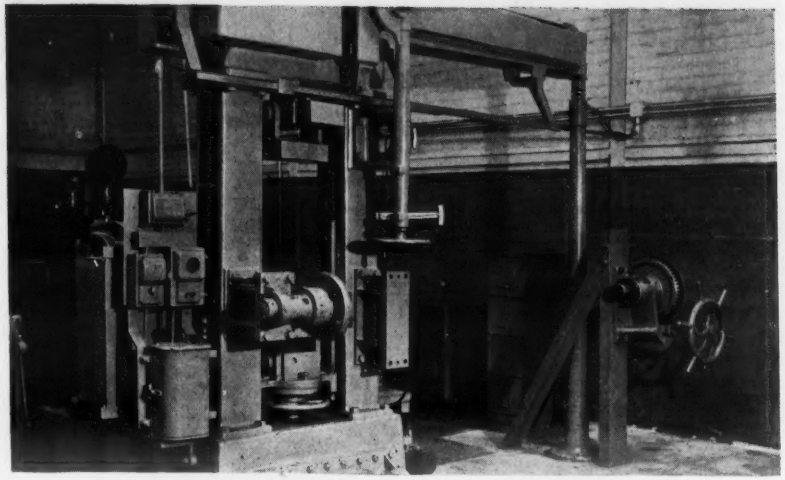


Fig. 1. Old material-testing machine converted for torsional test rigs.

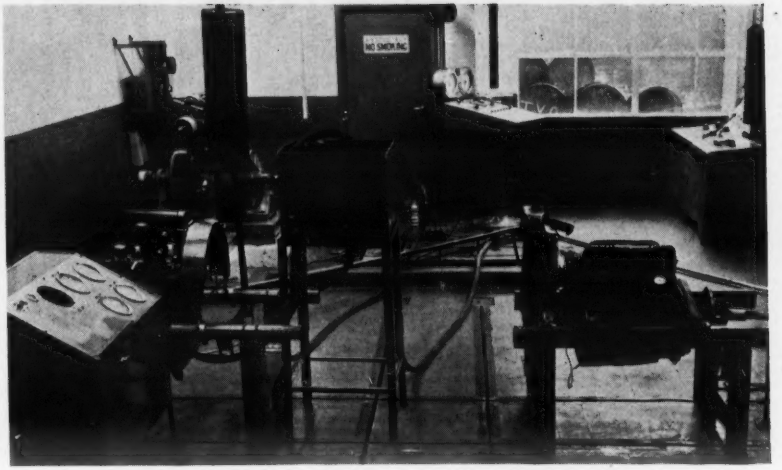


Fig. 2. Engine test-bed rigs.

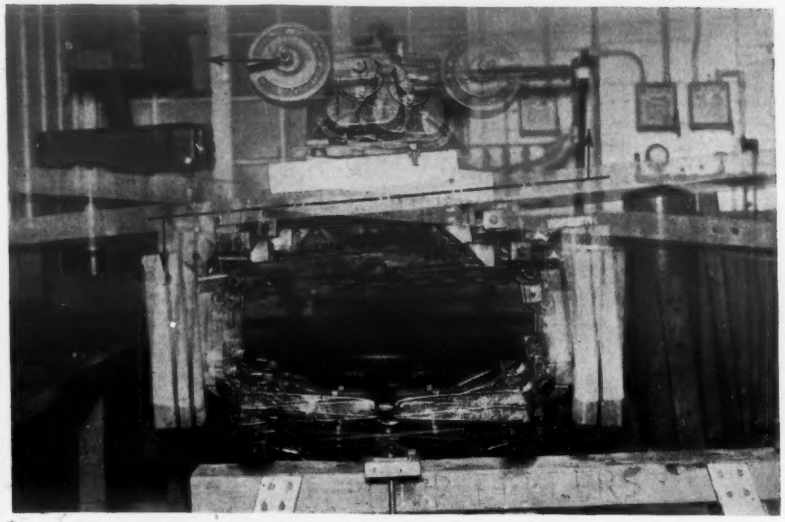


Fig. 3. Tuned vibratory motion. Double exposure to show instantaneous relationship between rotating weight and oscillating beam.

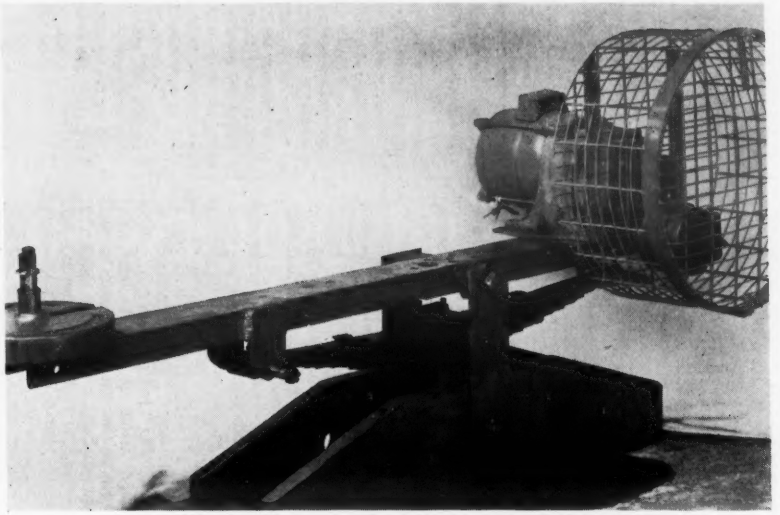


Fig. 4. Laminated-spring fixing bolts. Fatigue test of four bolts clamping spring at centre. Links hold spring in " loaded " condition.

mostly as the result of fatigue. Many years ago the author came to the conclusion that fatigue failure occurred as the result of tensile components of compound stress.

The author remembers a series of tests of case-hardened splined shafts using a torsion machine both in pure torsion and in combined bending and torsion. In pure torsion a helical crack started at the spline root, running in the usual manner at about 45 deg. through the splines, with one crack in each spline. When tested in combined bending and torsion, those cracks appeared only on the side of the shaft in tension, as, on the side under compression stress, the compressive component of stress arising from the bending moment counteracted the tensile stresses which caused the cracks in the brittle case of the shaft.

Under such conditions of static stress, the cracks start at the points of highest concentration of tensile stress in brittle material, in the same places where, in non-brittle materials, fatigue cracks would start under fluctuating stresses. For instance, in springs, fatigue cracks start at locations where tensile stress is a maximum, particularly in laminated spring blades, or in coil springs where failure starts at the inner surfaces in the plane of the tensile component of shear stress.

Modern technique uses brittle lacquers to produce similar results, enabling determination, under static stress, of the probable points of failure by fatigue when the part is subject to fluctuating tensile stresses.

In shock tests, a case-hardened surface will greatly reduce the resistance of the part, as again the tensile component is the critical one.

Frame fatigue failure

An early experience which aroused the author's interest in rig testing arose when, after nine months of extensive road testing, a frame cross-member failed by fatigue, and it was out of the question to run a further nine months or more to prove a redesign. A rig was therefore made which simulated the road stressing to an exaggerated degree. This produced exactly similar failure in two days, the rig having taken three or four days to contrive. The redesign was at once tested, found insufficient, redesigned and found satisfactory within the following fortnight. In subsequent years of road running on many thousands of vehicles, no failure has arisen.

No test can replace the road test for a road vehicle, but the above example illustrates the ideal use of shop rig tests (that is, to work quickly on a particular factor) in conjunction with road experience. Where possible the author has avoided the use of brute force, but rather has preferred to produce the fatigue stresses by the tuning of a small applied force to a chosen frequency of vibration.

On one occasion, when wishing to test the stiffness of a body scuttle, a 10-foot girder was bolted to it, but it still felt very stiff when operated by hand. However, when a 100lb. weight was bolted to each end of the girder it took only the timed pressure of the fingers to appreciably distort the structure. It is a short step from this arrangement to bolt on to the girder a small electric motor, in the first instance a geared motor running at 200 r.p.m. and having an out-of-balance weight of a few pounds.

Later, with the aid of variable speed motors, a wider freedom of test conditions became available. Usually the vibration period is arranged at about 100 r.p.m. If the suspension system of a vehicle is the subject of test, it may well be operated at springing periodicity. In such cases the shock absorbers must be inoperative, otherwise a small out-of-balance weight will not produce resonance. One does not wish large out-of-balance weights to be revolving at speed, with all the possible dangers involved, or small weights running at excessively high speeds.

There is a close connection between the technical department and test rig department, as it is often necessary to support calculations by actual tests, particularly if the structure under consideration is complex. Most calculations for stress or wear are of a comparative nature and not fundamentally related to physical properties of materials as determined from the usual test pieces. Calculated factors of safety for conditions where similarity exists in relation to previously proved designs are of great value. However, many instances occur where a test rig is arranged to confirm the conclusions arrived at by previous calculations.

"Tuned" Test Rigs. These are rigs devised to produce vibration of a single part or of a complete structure, by tuning the primary vibration frequency to the speed of rotation of an out-of-balance weight.

By these means, substantial vibrations of quite stiff structures can be arranged with quite limited means. All that is required is to "fix" the structure at one end, pivot it at the other end and secure at this point a beam carrying weights at its extremities. The moment of inertia of this "dumb-bell" is adjusted by choosing suitable girder weights until the vibration frequency matches the desired motor speed. Then, in its simplest form, a geared motor may be bolted to the beam, to drive an arm carrying the rotating out-of-balance weight. The amount of weight and its radius of swing are adjusted, to produce the desired amplitude of vibration, commensurate with the internal damping of the structure. The weight required at about 6-inch radius may vary from 2 to 30 lb.

Opposed Frames. An early example is shown in Fig. 3. This is an adaptation of the geared motor, vibrating two similar frames, mounted in looking-glass symmetry, one to the other. The top frame receives the rocking forces from the motor and is bolted to the lower one via packing blocks at the respective body-mounting brackets, so that the bottom frame is also vibrated. The reaction is taken by the rear end only of the lower frame being clamped in the spring testing machine, which is used for this purpose merely as a screw clamp. In the illustration this machine is hidden from view. As a rocking fulcrum, a rubber engine-mounting block supports the bottom frame, at the front end, on a wooden trestle. The chief purpose of introducing this illustration, is to "bring to life" the vibration produced by this type of rig and show how the motor itself partakes in the vibration. The relative directions of the centrifugal out-of-balance force and of the rocking couple are shown.

Spring Fixing Bolts. Quite a different application of the same motor is shown in Fig. 4. This rig was devised to simulate the alternate rise and fall of the front road wheels, in relation to an independent suspension system of the type using a laminated spring mounted across the frame, in conjunction with "wishbones."

The spring is shown attached to the base by four bolts and the spring shackled to the dumb-bell beam by a fixed shackle-pin at one end and a linked shackle at the other end. The links shown serve to hold the spring in the "loaded" condition while the ends of the spring are made to rise and fall by the swing of the beam. The location of the motor at one end of the beam and the weight at the other are arranged so that the system is "tuned" for 200 oscillations per minute. This rig produced fatigue failure of bolts in a similar manner to failures experienced on road test. Thus, material and bolt diameter sufficient to resist failure could quickly be determined.

Laminated Spring. The rig illustrated in Fig. 5 was driven by a variable-speed motor mounted in a dark room, with a hole in the wall for external driving. The object was to test blade interleaf materials.

A test of a normal spring produces surprisingly large amounts of "cocoa" from fretting corrosion at the blade tips.

A guiding link at the top of the structure assures vertical oscillations of the spring, which would be tuned to about 100 oscillations per minute.

Specimen Frame. The frame shown in Fig. 6 is merely a test piece, made up of tubular side-members and rectangular box cross-members. The object is to test the junction of the cross-members with the side-members under frame torsional movements.

In this type of frame, the side-members and cross-members are both subject to bending and torsional moments. There are bending moments in the cross-members equal in amount to the torsional moments in the side-members, and bending moments in the side-members equal to torsional moments in the cross-members. Stresses are a maximum at the junction of the members and it is here that careful design is required It is interesting to note how small is the amount of rotating weight which rocks this relatively stiff frame, when tuned with the weights shown.

Simple modification

On the first run, failure at a junction occurred in 5 minutes. A very simple modification to the method of welding gave many hours of "life" under this severe torsional fatigue test. This was to form a dimple in the rectangular cross-member directly over the tubular member, which when welded to the latter, transmitted the torsional moment in the side-member directly to the cross-member, which had previously been welded only at the sides.

Saloon Body. A body "in the white" mounted for rocking tests to determine weak joints, is shown in Fig. 7. This test was quite effective.

In order to make the stresses high, girders were used instead of flexible rear laminated springs, the body being mounted on its frame, which was pivoted at the front end. The dumb-bell weights shown are of amount to give a frequency of 200 oscillations per minute to suit the geared motor. Fig. 8 shows the geared motor in position. Note again how small is the out-of-balance weight which rocks this structure.

A more ambitious test rig is illustrated in Fig. 9 and 10. It took about two weeks to devise and construct. The principle is not one of tuning, but to a degree becomes so as the speed of running is set to suit the job. The drive was from a

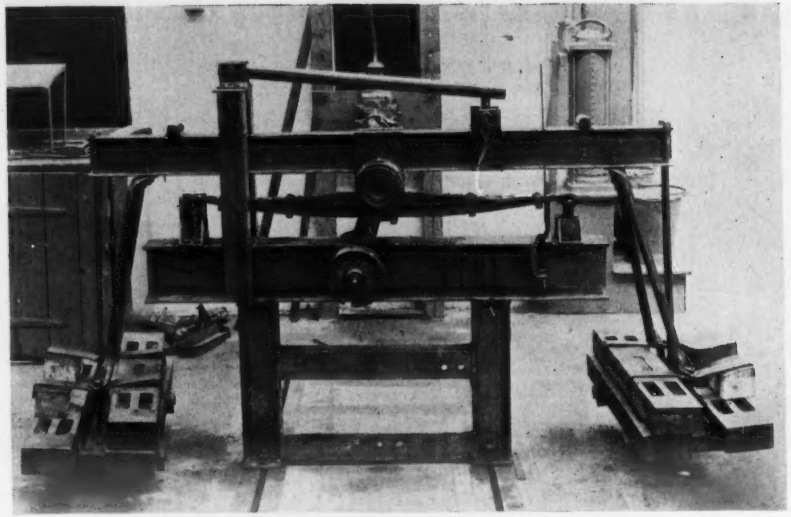


Fig. 5. Laminated-spring squeak test.

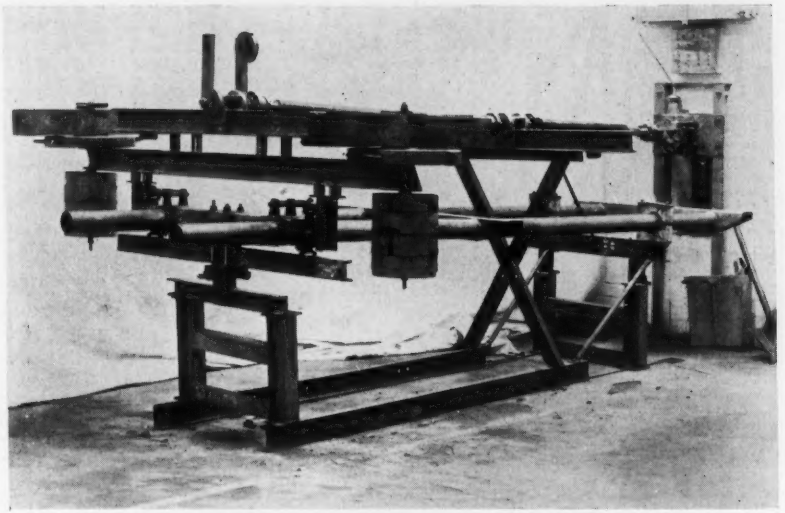


Fig. 6. Specimen frame undergoing torsional vibration.

Fig. 7. Body shell mounted for torsional oscillation.

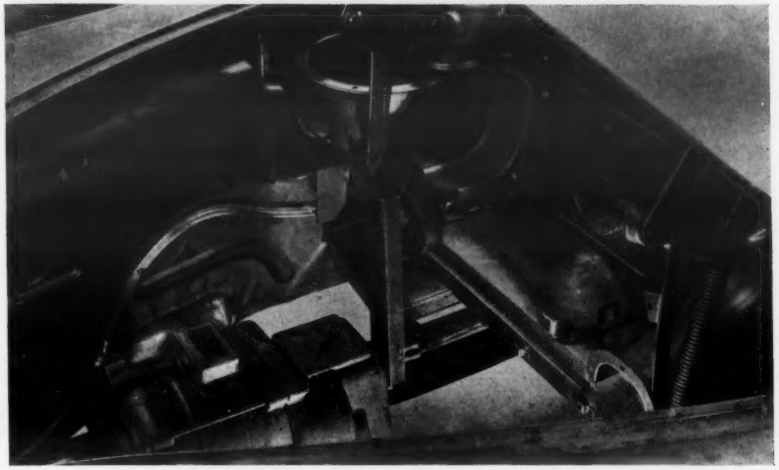


Fig. 8. Geared motor, mounted inside body, driving out-of-balance weight.

tractor engine, out of view on the right, through a tractor gearbox to provide high torque and low speed, which in this instance was a little over 300 oscillations per minute.

Two engine units without cylinder heads were mounted under oscillating girders that support the car, which had body "in white" loaded with bags of cast-iron shot. The girders were pivoted on plain bars at the outer ends and supported by piston crowns, the contact being by means of suspension bump rubbers to spread the load evenly on the piston crowns and save the need for means of articulation. Under these conditions, the load is less than the gas pressure for which pistons are designed. Nos. 1 and 4 pistons support one girder, whilst Nos. 2 and 3 support the other girder in the same line, and similarly for the off-side wheels. Lubrication for engine units was provided by a separate oil pump and 15-gallon oil tank.

The front wheels rise and fall alternately giving a twist to the car, while the rear wheels rise and fall in the opposite sense. As shown, the rise and fall is 3 inches. At this speed of operation, over 300 oscillations per minute, the girders would be thrown off the pistons, in the same way as a poppet valve would bounce if no valve spring was fitted. Therefore, two laminated springs were mounted below the cylinder blocks, adjusted for tension by tractor implement levelling links. This arrangement was impressive to watch and certainly shook the car, in which had been incorporated previously-determined strengthening features. No body or frame failure was produced, although tyres were worn out, rubbing against the guide bars. The rear trunk lid was subjected to heavy hammering, and engine movement on rubber mountings was pronounced.

Car Shock Loading. These test rigs were constructed before a shock testing course became available at the Nuneaton proving ground. They do not produce the effects of shock and whilst the simpler rigs have real value the more ambitious one just described is unsatisfactory for vehicle test.

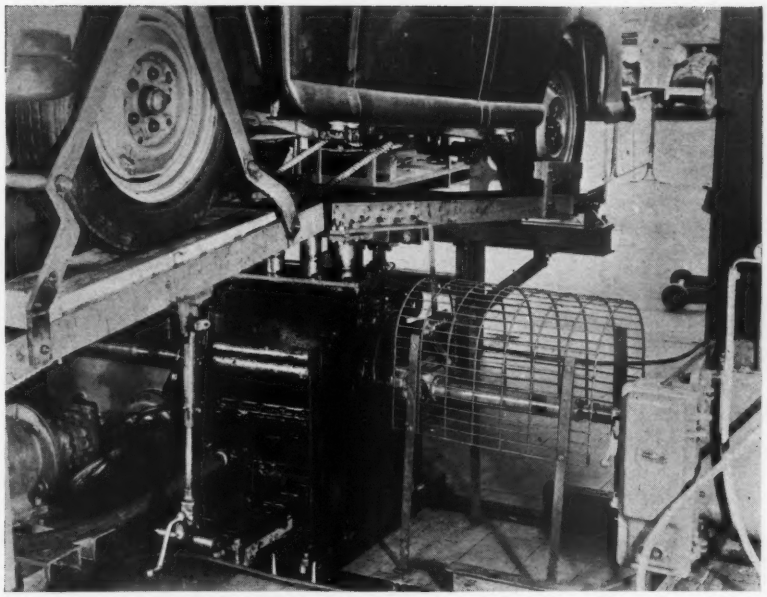


Fig. 9. Complete vehicle racking rig, showing drive and operating pistons.

The author is strongly in favour, for complete vehicle fracture testing, of the use of special test tracks designed to give the severe shocks which produce rapid fatigue. The track at Farnborough having kerbstones laid about every yard produces failures of the type experienced over high mileages on continental roads, but in a period of only a few days. We now have available to the automobile industry a half-mile strip of exaggerated Belgian pavé at the proving ground which is an excellent car breaker. The weak points found by the use of such a track should be strengthened before sending prototype cars on actual road endurance tests.

Combination of Tuning with Limited Amplitude. The use of tuning and the control of amplitude of vibration by variation of the amount of unbalanced rotating weight is only approximate, although it serves to find weak spots in a structure or part. However, when carrying out comparative tests on, say, coil suspension springs in order to test the relative value of various materials or resistance to corrosion of protecting finish, a constant stress range is desirable. This requires a limited amplitude of oscillation.

An adapted engine unit is shown operating two suspension coil springs in Fig. 11. Here, the principle employed is to load each spring with a weight, in this case a loaded arm, sufficient to give the desired periodicity to the whole system, when operated by hand. When the end of the arm remote from the fulcrum is urged to move by hand, this oscillation has a natural frequency due to the elasticity of the springs and the moment of inertia of the mass, including that of the crankshaft and flywheel. The crankshaft is then chain-driven at the natural period of vibration. Provided there is sufficient damping, this rig will operate with only slight bearing loads. Due to an error of judgment, the heavy weights shown were excessive so that the periodicity was too low, around 40 oscillations per minute, resulting in frightening oscillation when run at 80 r.p.m. In fact, on this occasion, the observers had to retire quickly to the safety of the adjacent darkroom, where the control switch was located. In its final form, this rig operates the arms without added weights. As the loads for these particular springs are well within the capacity of the engine bearings, even the arms could be dispensed with for these relatively light springs.

The engine piston has a hole in the crown to accommodate the arm operating rod, with a fork connection to the gudgeon pin. As the piston acts only as a cross-head, the piston bosses are reduced to make room for the fork. The rod is connected to the spring-compressing levers at a radius equal to the wishbone length for the comparable vehicle suspension

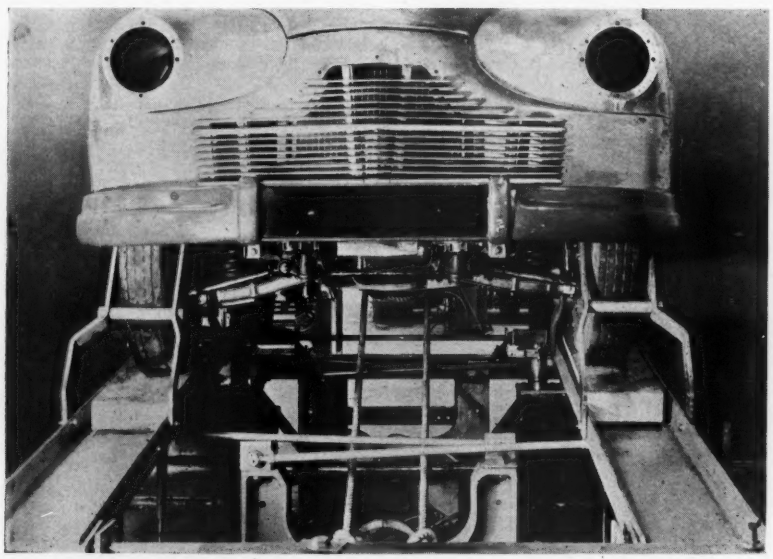


Fig. 10. Complete vehicle racking rig, showing radius arms and engine units for operating wheel-supporting beams.

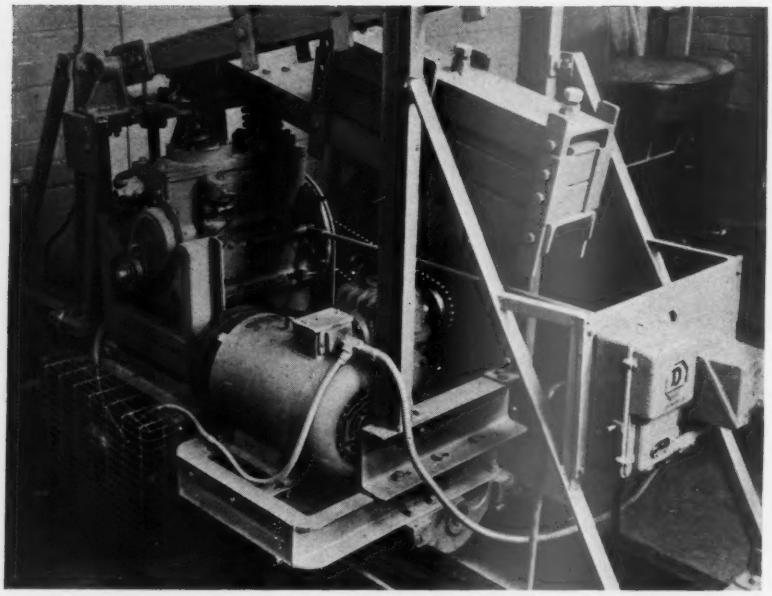


Fig. 11. Coil spring test rig. Springs are loaded by weighted arms.

system. This produces bending of the coils due to angular change of the levers as the spring oscillates.

The amplitude of spring compression is 92 mm which is equivalent to a road wheel vertical motion of 5.4 inches, allowing for the leverage ratio.

It might be interesting to record entire absence of front coil spring breakage, even on Austrian roads, when the springs have the following characteristics, as fitted to saloon motor-cars.

Material	Silico-manganese ground bar, shot peened
Static deflexion of road wheel ..	6.2 inches
Static stress ..	80,000 lb. per sq. in. (Wahl formula)
Maximum bump stress	125,000 lb. per sq. in.

In wishbone systems the spring is compressed most at the side farthest from the fulcrum, but it is at the side least compressed where the stress is highest. This factor has been taken into account in the above value.

Scrag solid	150,000 lb. per sq. in.

The author prefers to judge suspension spring stress on the values for static full load, and not to attempt to allow for the range of stress. Generally for normal vehicles, the stress range is so variable, the amplitude of road wheel motion varying continuously, that it would be difficult to determine a suitable value. If for a certain static deflexion a given static stress is permissible, then for a stiffer design lower stresses would be required, and for a more flexible design, higher stresses could be used. This follows because a stiff spring will tend to have a higher stress range than a flexible spring, under road conditions. This fact was well shown in the old days of laminated front springs and beam axles. Then, stiff front springs and flexible rear springs were used. Much higher static stresses were allowable in the rear springs than in the front, in the ratio of about 2 to 3.

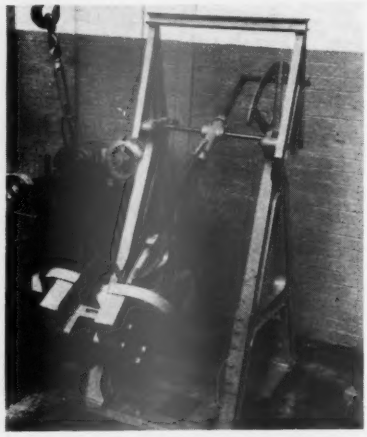


Fig. 12. Impact tester.

Impact Test Rigs. There may be two similar mechanical parts, one formed in brittle material and the other non-brittle. Under static load tests, such as in tensile testing machines, the brittle material may support greater loads than the non-brittle; thus, in order to determine the relative strengths under shock loads, impact tests are necessary.

For example, certain engines were failing owing to fracture of piston gudgeon pins; two makes of pin were used, one of which broke and the other did not. Under static bending loads the good pins failed at lower loads than the bad pins; only impact tests in a normal Izod machine disclosed the great difference between the pins, the bad pins fracturing at very low impact values, while the good ones remained unbroken under full impact of the machine. The main fault with the bad pins was an excessively thick case.

Surprisingly, it is found that the differential gears of a farm tractor are subject to heavy shock loads. The use of case-hardened bevel gears having a ductile core is imperative. Through-hardened steel is unsuitable. Fig. 12, shows one example of the use of a modified Izod test impactor. Note how the mass of the hammer-head has been increased. The impact readings on the normal quadrant scale are read as impact units instead of the original values of foot-pounds, each unit being 6.5 ft.-lb and the maximum energy of the blow 780 ft.-lb. The hammer is slung from an aircraft bomb slip, providing a simple release.

Bevel gear tests

When testing bevel gears, the hammer first hits a bar of metal, spring-loaded downwards (the spring is not shown in figure). If the tooth breaks at the moment of impact, this bar falls off its support out of the path of the hammer, so that no extraneous energy is absorbed to interfere with the impact readings, as shown in Fig. 13. This is only one of the many tests for which this heavy impact rig is used. Quite substantial structures, such as suspension linkages, are subjected to impact. Fig. 14, illustrates results of such tests to determine the strength of wishbone pivot brackets, the left-hand design remaining unbroken although the lever arms are bent.

While the heavy hammer will break a somewhat brittle single gear tooth, very severe methods are required in order to

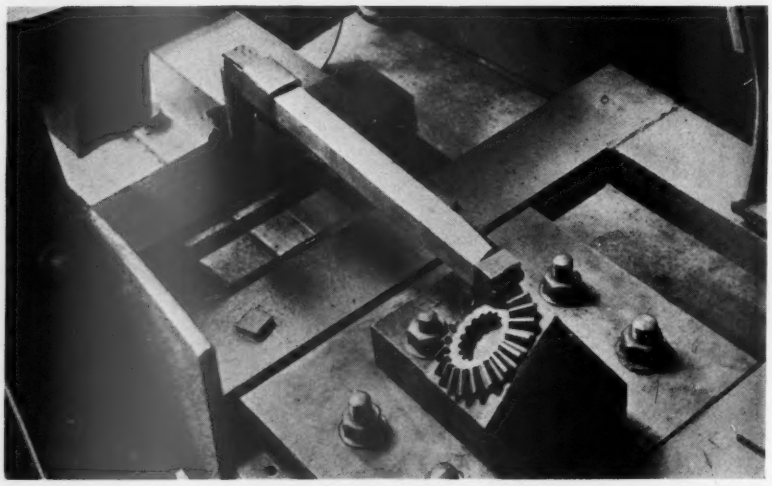


Fig. 13. Typical example of impact testing.

fracture a complete differential. In the rig illustrated in Fig. 15, an almost complete retractor is used. The engine runs at 2,000 r.p.m. and is fitted with a clutch, loaded with springs of twice normal force. The gearbox runs in first gear and drives the rotating sprag at 52 r.p.m. The land wheel at the opposite side is locked solid by application of the brake. At the desired moment the rebound pawl is released by means of remote control and air jack, then after a further few revolutions the stop pawl is released. Under the resulting impact, the opposite wheel is impelled to rotate through the differential, but, as it is locked, the whole transmission system is "shocked" as the clutch slips and the engine grinds down to rest. Shear pins, varying in number and radius, register the magnitude of shock torque. Even under this test the differential gears remain undamaged if of correct material, although the axle shafts bend.

Rig anchorage

The author would like at this point to advocate foresight when laying down testing shops. In the old days, concrete floors did not provide anchoring means for test rigs. Nowadays, when the concrete is laid, girders are placed with their top surfaces at floor level and grouted in. In the test house, the girders in plan form a large cross, while elsewhere numerous fixing points are laid down like tram-lines for lengths of about 15 feet, extending from boundary walls. There is consequently always somewhere to tie down a rig at short notice.

Transmission Tests. Rigs for testing gearboxes and rear axles are very effective and rank in quality and usefulness with the engine test bench. Sometimes an electric motor is used as a source of power, but the petrol engine is also used, because of its flexibility.

As an instance, a large commercial gearbox, while in the development stage, jumped out of every gear either on drive or overdrive and had bearing bush troubles also. By using a back-to-back test, all these faults were quickly dealt with, the various schemes for their elimination being the subject of prompt test. The set-up included a power-absorption dynamometer, normally a Froude water brake. This type will not absorb high torque at low speed, and to make it suitable for a transmission test where the gear ratio produces these conditions, two gearboxes are fitted back-to-back, the input and output speeds being equal and high enough to suit the dynamometer, when both boxes are running in the same gear ratio.

In Fig. 16, two tractor gearboxes, back-to-back, are being driven by a tractor engine, power being absorbed by a Heenan "dynamatic" brake, on an engine test stand. The floor is provided with fixing points for possible extensions such as this. The back-to-back arrangement is used in this rig for convenience even though this type of brake has high torque capacity at low speeds. The assembly already existed from previous tests where a Froude water dynamometer had been used.

The test in this instance is of resistance of plain bushes to overheating, running under full load in reverse without previously having been run in. As the dynamatic brake is reversible, the slave box nearest the brake could be operated in first gear, so confining the difficult reverse condition to the box undergoing test.

(*To be continued.*)

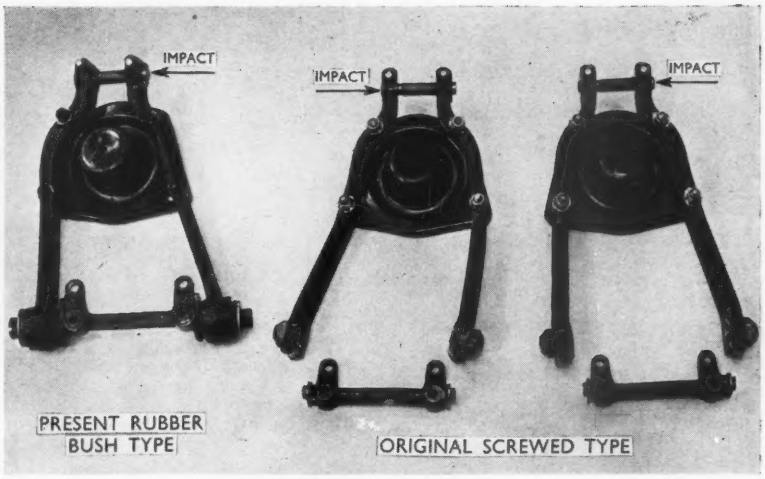


Fig. 14. Results of impact tests on suspension wishbone pivots. Left-hand pivot bracket remains unstrained after full impact.

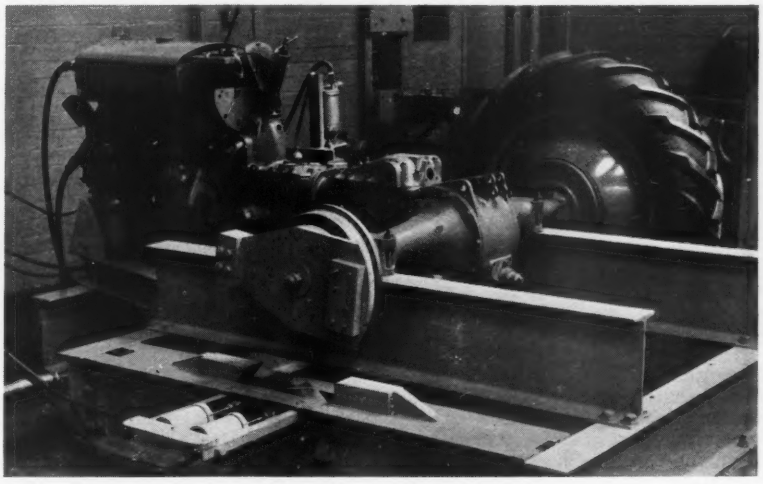


Fig. 15. Impact test on complete tractor transmission.

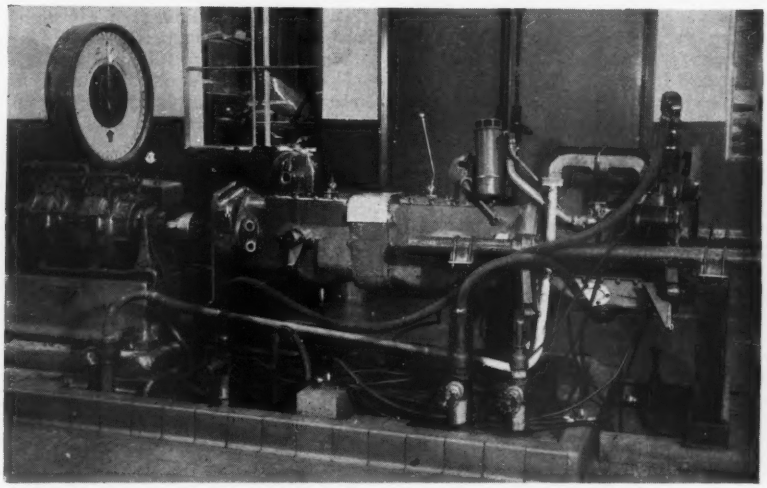


Fig. 16. Back to-back transmission test, using engine drive.

A section of the Mechanical Handling Exhibition.

MECHANICAL HANDLING

Some Notes on Modern Equipment Shown at the National Exhibition

THAT there is British equipment available for every form of materials handling was proved conclusively by the Exhibition recently held at Olympia under the ægis of our associated journal *Mechanical Handling*. Inevitably, many of the exhibits were not of direct interest to the automobile industry. These notes, therefore, do not purport to review the Exhibition as a whole, but will illustrate trends in equipment for use in automobile factories and in factories dealing with automobile accessories. In general they deal only with mechanical aids for the movement of goods or components within the factory.

There is, of course, no one method of internal transport that is suitable for all applications. Some are best dealt with by conveyor, others by trucking. Each of these forms of internal movement has a considerable number of variations and the final selection will be determined only after many factors have been weighed. The Exhibition did afford a good opportunity for comparing, first the different methods, and then the range of equipment offered by different makers.

Trucks

In the internal movement of goods within a factory the introduction of the fork truck has probably been the most important development of recent years. The fork truck is, in fact, now considered to be an essential item of equipment in many factories. It is, therefore, not surprising that fork trucks were one of the outstanding features of the Exhibition.

Coventry Climax Engines, Ltd., Widdrington Road, Coventry, showed some recent developments in addition to their established range of fork trucks. One was a model T.S.M. fork truck powered by an 8 h.p. 4-cylinder petrol engine. This truck has a capacity of 1,500 lb and will stack to a height of 9ft. Manœuvrability is an important factor in much fork truck work, and this model will pass along an aisle 36in wide with room to spare and has a turning circle of 56in radius. It will also pass through a 6ft high doorway when fully laden.

Another Coventry Climax exhibit was a T.S.M.-D. fork truck with a Coventry diesel engine. It has a capacity of 2,240 lb at 15in from the fork heel, and will stack to a height of 9ft. Although not quite so manœuvrable in confined spaces as the T.S.M. petrol model it has quite good manœuvrability and will pass down an aisle 36in wide and has a turning circle of 62in radius. It has a maximum speed of 8.52 m.p.h. both forward and reverse.

Reference may also be made to two Coventry Climax attachments which can simplify fork truck operation. One, the side shift carriage attachment, provides an easy means for the accurate positioning of palletized loads. Briefly, the mechanism comprises a special fork carriage that can be moved laterally across the truck to a distance of 3in either side of centre. A jack connected to the main hydraulic system operates the attachment.

If the forks have to be accurately positioned in pallets or under other types of unit loads, the side shift attachment will eliminate much of the necessity for truck manœuvring. It is also useful when stacking has to be carried out in narrow aisles or confined spaces, since it provides a means for close, rapid positioning of loads.

The second attachment is a powered revolving fork carriage designed for a complete 360 deg revolution in either direction. It is directly controlled by the driver. This attachment is fitted with standard forks and in suitable applications it can considerably reduce the amount of handling needed. For example, in emptying metal scrap bins, a loaded bin is picked up by the forks and carried to its destination, where it is lifted and rotated so that the scrap is dumped while the bin itself is held by the forks. This attachment can be used for any loads that are suitable for dumping. A truck fitted with this attachment can also be used for all conventional fork lift operations.

Lansing Bagnall, Ltd., Basingstoke, Hampshire, exhibited several recent developments. Perhaps the most interesting was the pedestrian-controlled electric fork-lift truck, the first of its type to be produced in this country. It is designed for all types of loading and unloading operations, and for handling and stacking materials on pallets. Because of its dimensions, it

is more suitable than the conventional fork truck for use where the gangways are narrow. Further, because of its low unladen weight it can be used on the upper floors of multi-storey buildings where lift and floor loading restrictions do not allow the orthodox type of fork truck to be used to full advantage.

There are three models of 12 cwt, 15 cwt, and 1 ton capacity. They may have either an electro-hydraulic lift of 5ft 8in or a telescopic lift of 10ft 11in. This truck incorporates the Lansing Bagnall power unit. It is easily controlled by means of a twist grip handle, and the front wheel power drive gives freedom for manœuvring sharp corners and in narrow aisles. A built-in charger allows the batteries to be charged from any convenient 15 amp power point. The hydraulic lift and tilt motion are operated by convenient handles.

A fork truck development of considerable interest was exhibited by Mathew Brothers, Matbro Works, Sandy Lane North, Wallington, Surrey. In general, fork trucks have been developed for use inside factories on hard level surfaces, but this new fork truck, the Matbro "Pneustac" has been developed for use in open yards where the surface may be comparatively rough and soft. It is also intended for use over longer distances than are usually considered economic for fork trucks, and consequently it has been designed to have a higher speed than has hitherto been common for fork trucks.

There are four models. Two are powered by 36 h.p. 6-cylinder Perkins diesel engines, and two by 36 h.p. 4-cylinder Fordson petrol engines. All four models have a lifting capacity of 4,480 lb at 18in from the heel of the forks and will lift to a height of 9ft. Giant pneumatic tyres are fitted on the driving wheels.

Despite the wide scope for fork trucks there are still many applications for which some other form of trucking transport is more suitable and more economical. Among other exhibits, Douglas (Sales and Service), Ltd., Bristol, showed two very interesting trucking developments. One, the Douglas "Ape," comprised a truck and a trailer powered by a two-stroke single-cylinder engine that gives a maximum of 4 b.h.p. at 4,500 r.p.m. Both the truck and the trailer are designed for carrying loads of up to 5 cwt.

There are many applications in which some degree of lift is desirable, but of a lesser order than is possible with a fork lift truck. For such applications there was the Douglas High Lift truck. This truck is designed for the transport of stillages. The driver can pick up loads without leaving his seat, and the load can be lifted to any height between 1ft 7in and 4ft 8in. The maximum load, 25 cwt, can be raised from the lowest position to maximum height in 20 seconds. Power for both moving and lifting is provided by a Douglas 596 c.c. air-cooled flat twin engine.

Conveyors

Almost every type of conveyor was exhibited. Those of particular interest to the automobile industry ranged from simple gravity roller types to many different kinds of overhead conveyors. Most of the gravity roller conveyors were of well-established designs, but a new development was exhibited by Lamson Engineering Co., Ltd., Hythe Road, Willesden, London N.W.10. This was a skate wheel conveyor weighing only 29 lb per 8ft length. It has wheels at 3in pitch, is 14½in wide, and can carry an evenly distributed load of 150 lb. The conveyor is mounted on special tripods that are adjustable from 28in to 46in height. Because of its light weight, this conveyor can be erected or dismantled by one man. It is therefore particularly suitable for use in loading bays where there is no need for frequent change in the position of the conveyor.

The products of Geo. W. King, Ltd., Hitchin and Stevenage, Herts, need no introduction to the automobile industry. So far as was possible within the confines of an exhibition stand they exhibited a representative selection of their many different aids for mechanical handling. Particular attention may, however, be drawn to one of this Organization's more recent developments, the "Power - pulled Junior" conveyor, which has been developed for handling light loads.

There are two types, the "open" and the "flushed." The open type will carry loads up to 30 lb at multiples of 6in, while the flushed type will carry loads up to 30lb at multiples of 4in or 6in. For heavier loads, double suspension is used in each case. An outstanding feature of the open type is the small radius that can be negotiated. With the trolleys at 12in pitch, the normal vertical bends have a radius of 2ft, but special arrangements can be made to employ a radius as small as 9in for both horizontal and vertical bends.

The unit construction conveyors exhibited by Teleflex Products, Ltd., Chadwell Heath, must also be of interest to engineers wishing to install an overhead conveyor for light articles. Briefly, the Teleflex system consists of a patented Teleflex cable running within a rail assembly made up of standard straight sections and horizontal and vertical bends. The cable in effect forms a continuous rack to which the carriers are attached.

Normally this type of conveyor can be arranged to run at any speed from zero and 15ft per minute. The average load is 60 lb with the carriers at 3ft centres, but this is in some degree dependent upon the shape of the conveyor. Quite small radii can be negotiated. For drive and corner units the minimum is 9·875in pitch circle radius of cable, and for rise and fall assemblies the minimum is 15·562in. The maximum angle of rise or fall is 35 deg to the horizontal.

One exhibit that has a wide range of uses was shown by Barron & Shepherd, Ltd., 251, Cromwell Road, London, S.W.5. It is called the "Lowerator," and is in effect a work container with a spring compensated platform. It is so arranged that the platform sinks as articles are loaded on, so that the top level of the articles always remains at a predetermined height set to suit the convenience of the operator. Conversely, as articles are removed the platform rises to maintain the same convenient height.

The Lowerator can be a fixture or can be handled by fork truck, platform truck or conveyor. It can also be mounted on wheels to become a handling, storage and transportation unit in one. Its only motive power is the spring compensating mechanism, which is adjustable within limits so that one unit can handle different weights.

In every factory there is always need for some space that is used only for storage. Such space is non-productive. Therefore the general aim in every factory layout is to keep storage space to as small an area as possible. The most recent techniques make it possible to store a given quantity of goods in about one-half of the space previously required without any loss of accessibility. Examples of the equipment for giving improved use of storage space were exhibited by Fisher & Ludlow, Ltd., Gridway Division, Rolfe Street, Smethwick, Staffs, and by Acrow (Engineers), Ltd., 33, Catherine Place, London, S.W.1.

Both systems are based on the same principle. Briefly, this is, that the rear row of shelves or bins are fixed, and mounted in rows in front of them are units that slide on rails. Each row of sliding units has one less unit than there are in the fixed row. This allows several rows of bins to be served from a single gangway since to get at any specific bin in the rows remote from the gangway, it is merely necessary to move the units in front so that the empty space in each row is at the appropriate point.

"Model Engineer" Exhibition

THE Exhibition will take place during the month of August at the New Horticultural Hall, Westminster, London, S.W.1. It will open on Wednesday the 9th and close on Saturday the 19th. There will be the usual display of model cars, aeroplanes, speed boats, locomotive engines, etc., and the first twin-engined radio-controlled aircraft in the world to fly will be on view. As in full-scale industry, great advances have been made in machinery and tools for the model engineer's workshop. Equipment of this kind will form an interesting and important section of the Exhibition, a special feature being the high grade, and precision character of many of the exhibits.

CURRENT PATENTS

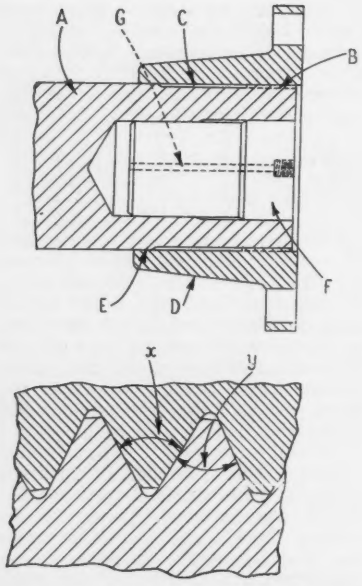
A Comprehensive Review of Recent Automobile Specifications

Demountable torque–transmitting joint

CAPABLE of transmitting torque in either direction, this joint will permit the ready connection or disconnection of two parts with consistent accuracy. It is suggested, not exclusively, that it may be used where the crankshaft of a multi-cylinder engine is built in two parts which are joined so that the torque of the engine may be taken in the centre of the length of the rotating system. Several arrangements are shown in the specification and the one illustrated is intended to prevent any possibility of the outer member rocking as the result of the imposition of a bending moment. On the exterior of the inner member A are formed serrations B and a relief C of a diameter approximately the same as that at the bottom of the grooves between the serrations. The outer member D has a complementary series of serrations of similar axial length and at E is a push fit on the main diameter of the inner member A.

These serrations, as they appear in transverse section, are individually of wedge shape and have the form of screw threads. The included angle x of the serrations of the outer member is 60 deg while the included angle y of those of the inner member is 56 deg. In both instances the tips of the serrations are removed.

The end of the inner member is bored axially to two diameters to receive a parallel plug F of an interference fit calculated to expand member A to an amount sufficient to bring the wedge-like faces of the serrations into intimate contact. A hole G drilled through the plug allows the escape of air when the plug is being inserted and is screw threaded at its outer



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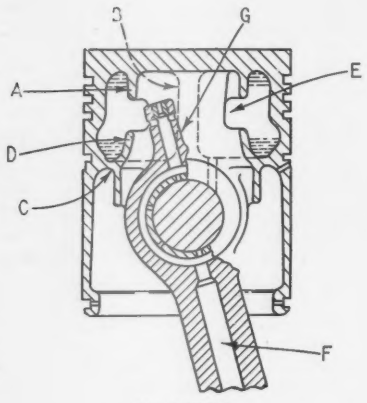


No. 617224

end to receive a connection from a hydraulic pump by means of which liquid under pressure can be introduced to drive out the plug when it is desired to dismantle the joint. *Patent No.* 618928. *H. R. Ricardo and R. W. Cousins.*

Oiled-cooled piston

TO promote the extraction of heat from the wall of a piston, particularly in the way of the piston rings, and to reduce the heat transferred from the crown, oil delivered from a jet or jets in the end of the connecting rod is retained in internal troughs formed in the piston and washed back and forth during reciprocation. It is claimed that by this method considerably more heat can be taken away than by a corresponding quantity of oil either projected as a jet against the piston crown or circulated through a substantially closed chamber. The example illustrated is typical of a number of alternative designs detailed in the specification.

On the underside of the piston crown is an annular projection A which merges into the stiffening ribs B extending from the crown to the gudgeon pin bosses. Spaced from the crown, approximately at the lower extremity of the ring land, is a flange C having an upstanding lip D which also merges into the ribs B. The opposed troughs so formed constitute a pair of oil chambers into which oil enters and leaves by way of the slot E.

Oil delivery, preferably timed by the disposition of ports and passages in the big-end bearing and crankpin, is by way of the passageway F, an annulus in the small end and drillings in the small end projection G. One jet may be delivered directly to the piston crown. *Patent No.* 617224. *H. R. Ricardo, G. A. Holt and R. Watts.*

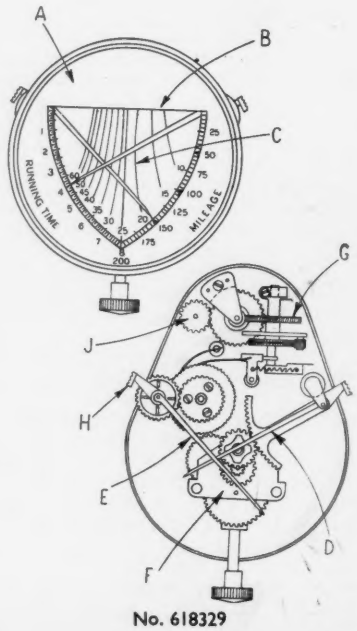
Average speed indicator

WHEN it is desired to travel a considerable distance in a specified period of time the average speed to accomplish this can be calculated without difficulty. To ensure that the aim is fulfilled, however, it is desirable to know whether the necessary average has been maintained under the conditions prevailing and taking into account voluntary or involuntary delays. This instrument uses co-operating indicators of total mileage and elapsed time to show average speed at any point of the journey.

A dial A has a pair of graduated scales formed by describing circular arcs from opposite ends of the horizontal base line B. The portion of the dial located between the scales is marked with a set of average speed curves C correlated with the mileage and time scales and covering a range from 10 to 60 m.p.h. in steps of 5 m.p.h. Each of these curves is the locus of the point of intersection of two straight lines drawn from the ends of the base line to values on the mileage and time scales, and in practice is indicated by the intersecting lower edges of the pointers D and E. Pointer D is driven by a clockwork mechanism F and acts as the hour hand, while pointer E is driven through a reduction gearing G by the normal speedometer drive.

In the example, the mileage scale reads up to 200 and the time scale to 8 hours and the straight line joining the intersection to the centre of the base line consequently represents an average speed of 25 m.p.h. Both pointers are frictionally held to their spindles and can be reset by means of external levers H.

The specification describes the train which, by means of spur gears, worm and wheel, vernier type planetary gear, and cam-actuated pawl and ratchet wheel, affords a reduction ratio of 1,920,000 : 1 between the initial drive point at pinion J and the pointer E. *Patent No.* 618329. *Morris Motors, Ltd., and H. F. Landstad.*



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